PB84-152768

Ground Water Management in the Southeastern United States

Oklahoma Univ., Norman

Prepared for

Environmental Protection Agency, Washington, DC

Sep 83

U.S. Department of Commerce
National Technical Information Service
NTIS

United States
Environmental Protection
Agency

Office of Exploratory
Research
Washington DC 20460

EPA-600/2-83-090
September 1983

Research and Development

PB84-152768

Ground Water Management in the Southeastern United States

Final Report

1

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-83-090	2.	3. RECIPIENT'S ACCESSION NO. PB84 152768
4. TITLE AND SUBTITLE Ground Water Management in the Southeastern United States		5. REPORT DATE September 1983
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Michael D. Devine and Steven C. Ballard		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Science and Public Policy Program University of Oklahoma Norman, OK		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. CR809273-01-0
12. SPONSORING AGENCY NAME AND ADDRESS Office of Exploratory Research Office of Research and Development U.S. Environmental Protection Agency Washington, DC 20460		13. TYPE OF REPORT AND PERIOD COVERED
		14. SPONSORING AGENCY CODE EPA/600/20

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This study characterizes current and potential ground-water resource problems in North and South Carolina, Georgia, Florida, Alabama, Mississippi, Tennessee, and Kentucky. It discusses those issues that could constrain development or adversely affect environmental quality or human health in the eight-state area. It contains case studies illustrating how several state and local governments are dealing with ground-water problems and assesses the applicability of these experiences to other areas. It addresses ground-water quality in relation to hazardous waste disposal, nonpoint source pollution, monitoring strategies and deficiencies, and drinking water quality. The report also details technical and institutional options for managing groundwater quality and availability.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
	20. SECURITY CLASS *(This page)*	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

EPA-600/2-83-090
September 1983

GROUND WATER MANAGEMENT IN THE SOUTHEASTERN UNITED STATES

FINAL REPORT

by:
Science and Public Policy Program
University of Oklahoma

Michael D. Devine
Steven C. Ballard
Basil G. Achilladelis
Lisa M. Butler
Larry W. Canter
Michael A. Chartock
Deborah M. Fairchild
Elizabeth M. Gunn
Carol P. Holloway
Thomas E. James, Jr.
Donna V. Kutsal
Gary W. Miller
Rebecca S. Roberts

Project Directors: Michael D. Devine
Steven C. Ballard

Prepared for:
Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C. 20460

Project Officer:
Charles B. Oakley
Office of Strategic Assessment and Special Studies

Cooperative Agreement Number CR 809273-010

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

June 1983

DIGEST

GROUND WATER MANAGEMENT IN THE SOUTHEASTERN UNITED STATES

Purpose

This study characterizes ground water resource problems in eight southeastern states.* Its general purposes are to identify emerging ground water quality and availability issues, to inventory policy options to deal with these issues, and to assess the feasibility of these options for the conditions likely to exist in the Southeast. This report is intended to inform decisionmakers at all levels of government and in the private sector who have responsibility for water policy and planning, as well as the environmental research community and the general public.

Scope and Approach

The Science and Public Policy Program at the University of Oklahoma conducted this study for the the Office of Exploratory Research of the United States Environmental Protection Agency. Four research tasks were performed: (1) a review and integration of existing information on ground water problems and issues, (2) four site-specific case studies in Florida, Georgia, North Carolina and South Carolina, (3) a ground water management workshop to discuss problems, issues, and policies, and (4) an inventory and preliminary assessment of ground water management options. The study assessed current ground water problems as well as those likely to occur over the next two decades. In addition to the eight southeastern states, the ground water management experiences in many other states were reviewed.

Ground Water Problems

Two conditions will contribute to increased demands and stresses on ground water in the Southeast: increasing population and industrial growth and the technical, financial and institutional complexity of ground water management. This report reviews circumstances related to the rural and agricultural economy, industrial characteristics, the hydrogeological and environmental setting, and political institutions that contribute to the development of ground water quality and availabilty problems.

---

*The eight states, which comprise Federal Region 4, are: North and South Carolina, Georgia, Florida, Alabama, Mississippi, Tennessee, and Kentucky.

Ground water quality problems have been directly related to locally intensive land uses such as hazardous waste disposal facilities, landfills, mineral production, and the storage and transport of fuels and chemicals. Widely dispersed yet pervasive sources of pollution in rural and suburban areas have also affected ground water quality, particularly in those areas with shallow water tables. Important sources include septic tanks, agricultural fertilizers and pesticides, and runoff. Naturally poor quality ground water also contributes to management problems, particularly along the coastal plain.

Ground water availability problems, especially in the coastal plains region are intensifying because of increased demands for irrigated agriculture and the growth of recreational and metropolitan centers. Local cases of overdraft, which can result in lower water tables, degradation of ground water quality, reduced ground water availability, and subsidence, are likely to continue to intensify during seasonal peak use and drought periods. Although trends toward a greater use of ground water are widespread on a regional basis, problems are frequently managed by unique, localized, or ad hoc approaches.

Policy Options

Four categories of policy options were assessed: (1) options to protect ground water quality, (2) options to insure adequate supply, (3) land use management, and (4) state and local institutional development. Within these categories 47 options were briefly discussed and 31 were evaluated in more depth to determine their current status, advantages, disadvantages, and feasibility for the Southeast:

- Options for enhancing the protection of ground water quality included: the controls over pollution sources; the development of standards for ground water quality management such as ambient standards, effluent standards, aquifer classification standards, and rehabilitation of aquifers or treatment of ground water;

- Options for managing water availability included: improved water allocation frameworks; alternatives that increased supply, such as surface water use, well field management, desalination, and artificial recharge; and alternatives that managed demand, such as conservation, pump taxes and pricing alternatives;
- Land use management options included: comprehensive planning that encompasses natural resource values; land use information for ground water management, and land use controls such as zoning and construction standards; and
- Institutional options to improve state and local government capacity to manage ground water included: integrated administration of quality and availability; conjunctive use of surface and ground water, emergency response capabilities, critical use areas, and cooperative (regional) supply systems. Comprehensive frameworks for managing ground water resources are also discussed; institutional models of several different degrees of centralized authority are compared, based on the experiences of three states.

Perspectives

The states in the Southeast have extensive ground water systems and an abundance of lakes, rivers, and streams as sources of water supply. However, there has been an increasing awareness of the need to manage ground water resources in order to ensure adequate supplies of high quality water. This is particularly true at the administrative level of state governments and in many local governments, but it appears to be less true in many state legislatures. Virtually every southeastern state has recently developed improved ground water management capacities. At least three states have developed relatively comprehensive and innovative policies--Florida's comprehensive regulatory system, Georgia's integrated administrative approach, and North Carolina's classification system. However, many problems still exist; most states and many local governments will continue to evaluate and develop options for dealing with emerging ground water concerns.

Although many alternative technologies and strategies are available for dealing with water supply and quality problems, no single option or category of options is likely to resolve these problems. Further, what is appropriate in one situation is not necessarily transferable to others. The selection of the appropriate options to address a particular problem depends on the context within which it will be implemented, including the driving forces behind the problem, hydrogeologic characteristics, political circumstances, resource requirements and demands, and the availability of new technologies. No single administrative/regumodel can be defined which can be transfered from state to state and implemented with similar results--the history and context of an area will largely determine the most appropriate institutional structure for dealing with ground water issues.

While important differences exist, many similarities also exist across the region. These include increased demands for ground water use, growing awareness of conservation problems, and, growing realization of the significance of ground water to the economic and environmental quality of the states and the region. A variety of valuable experiences in identifying ground water problems and developing management strategies can be found across the Southeast. These experiences need to be shared among state and local governments in the Southeast and in other states facing similar problems. In addition, most states will need infrastructure and financial support to coordinate, plan, and carry out ground water management policies.

CONTACTS

For further information on this project, please contact one of the following sources:

Mike Devine/Steve Ballard
Project Directors
Science and Public Policy
Program
601 Elm Avenue, Room 431
University of Oklahoma
Norman, Oklahoma 73019
405-325-2654

Charles Oakley
Project Officer
Office of Strategic
Assessment
U.S. Environmental
Protection Agency
Washington, D. C.
202-382-7449

PREFACE

This report on Ground Water Management in the Southeastern United States has been prepared as a part of "An Integrated Environmental Assessment of Federal Regions 4 and 6: Phase II," conducted by the Science and Public Policy Program (S&PP) under a cooperative agreement with the Office of Strategic Assessment and Special Studies, Office of Research and Development, U.S. Environmental Protection Agency. The overall purpose of this study, begun in October 1980, is to identify and assess future environmental trends in the region and to evaluate alternative strategies for environmental protection. An earlier report Southern Regional Environmental Assessment: Environmental Status Report,[1] produced as part of Phase I of the study, identified key driving forces and current and future environmental concerns. Following this initial effort, attention was turned to ground water resources. The purpose of this part of the study is to assess current and emerging ground water problems and management issues and to identify policy options that could be used to improve the management of this resource.

The Project Directors are Michael D. Devine, Director of the Science and Public Policy Program and Professor of Industrial Engineering and Steven C. Ballard, Assistant Director of the Science and Public Policy Program and Associate Professor of Political Science.

Other members of the research team from the Science and Public Policy Program are: Basil G. Achilladelis, Associate Professor of Chemistry; Lisa M. Butler, Graduate Research Assistant (Geography); Michael A. Chartock, Associate Professor of Zoology; Elizabeth M. Gunn, Graduate Research Assistant (Political Science); Carol P. Holloway, Graduate Research Assistant (Public Administration); Thomas E. James, Jr., Assistant Professor of Political Science; Donna V. Kutsal, Graduate Research Assistant (Public Administration); and Rebecca S. Roberts, Assistant Professor of Geography. Several other persons affiliated with the National Center for Ground Water Research at the University of Oklahoma also contributed to this study: Larry W. Canter, Director, National Center for Ground Water Research and Professor of Civil Engineering and Environmental Science; Deborah M. Fairchild, Environmental Scientist; and Gary D. Miller, Assistant Professor of Civil Engineering and Environmental Science.

---

[1] Science and Public Policy Program. 1983. Southern Regional Environmental Assessment: Environmental Status Report. Cincinnati: U.S. Environmental Protection Agency.

ACKNOWLEDGEMENTS

The research reported here could not have been completed without the assistance of a dedicated administrative support staff. Members of the staff worked closely with the authors and are an integrated part of the research approach employed by the Science and Public Policy Program. Staff members include: Mary Zimbelman, Assistant to the Director, Lennet Bledsoe, Clerical Supervisor, and Laura Marburger, Nick Evans, and Deborah Kasbaum, Clerk-typists. Emily Terrell, Science and Public Policy Librarian was of valuable assistance in obtaining and organizing source materials.

The EPA project officer, Charles B. Oakley, Office of Strategic Assessment and Special Studies, provided essential assistance in implementing the project's workplan. This work was also facilitated by John Reuss, Acting Director of the Office of Strategic Assessment and Special Studies, and by Robert Roth, Chief, Management Branch, Region IV, Environmental Protection Agency. Other Region IV staff that provided valuable suggestions included John Mann, John Mason, and Jean Tolman. David Hill, Environmental Research Laboratory, Athens, Georgia, also provided helpful suggestions.

Participants in a Ground Water Management Workshop, conducted October 28 and 29, 1982, also provided valuable help in completing this report. These participants included: Donald Duncan, Director, Ground Water Division, South Carolina Dept. of Health and Environmental Control; Walter L. T. Hang, New York Public Interest Research Group; Jack Keeley, Chief, Ground Water Research, Robert S. Kerr Environmental Research Laboratory; Jon Kyl, attorney, Phoenix, Arizona; John Mason, Environmental Protection Agency, Region IV; Marian Mlay, Deputy Director, Office of Drinking Water, Environmental Protection Agency; James Tripp, Staff Counsel, Environmental Defense Fund; and Douglas Yoder, Assistant Director, Metro-Dade County Dept. of Environmental Resources Management.

The Science and Public Policy Program acknowledges the valuable assistance provided by many other individuals who reviewed drafts of this report, provided information, or in other ways contributed to the project.

TABLE OF CONTENTS

GROUND WATER MANAGEMENT IN THE SOUTHEASTERN UNITED STATES

FINAL REPORT

Page

Digest iii
Preface vii
Acknowledgements ix
List of Figures xv
List of Tables xvii

SUMMARY. S-1

CHAPTER 1: WATER AND GROWTH ISSUES IN THE SOUTHEAST

1.1: INTRODUCTION 1-1

1.2: GROWTH IN THE SOUTHEAST. 1-2

1.3: WATER RESOURCE CONCERNS. 1-8

1.4: PURPOSES, SCOPE, AND AUDIENCE. 1-12

1.5: ORGANIZATION OF THE REPORT 1-13

REFERENCES 1-15

CHAPTER 2: WATER RESOURCE CONCERNS IN THE SOUTHEAST

2.1: INTRODUCTION 2-1

2.2: WATER RESOURCES. 2-2

2.3: WATER USE PATTERNS 2-8

2.4: WATER RESOURCE PROBLEMS AND ISSUES 2-15

2.5: SUMMARY. 2-35

REFERENCES 2-39

Table of Contents: (Continued)

Page

CHAPTER 3: CASE STUDIES IN THE SOUTHEAST

3.1: INTRODUCTION TO THE CASE STUDIES 3-1

3.2: COLUMBIA, SOUTH CAROLINA STUDY AREA. 3-3

3.3: GEORGETOWN TO WILMINGTON CASE STUDY DESCRIPTION. 3-22

3.4: SOUTHEAST FLORIDA-BISCAYNE AQUIFER CASE STUDY. 3-44

3.5: HENRY COUNTY, GEORGIA. 3-62

3.6: SUMMARY OF CASE STUDIES. 3-69

REFERENCES 3-73

CHAPTER 4: GROUND WATER QUALITY PROBLEMS AND ISSUES

4.1: INTRODUCTION 4-1

4.2: HAZARDOUS WASTE DISPOSAL 4-2

4.3: NONPOINT SOURCE POLLUTION AND LAND USE PRACTICES 4-23

4.4: GROUND WATER MONITORING. 4-47

4.5: DRINKING WATER QUALITY 4-64

4.6: INSTITUTIONAL AND MANAGEMENT ISSUES. 4-78

4.7: SUMMARY AND CONCLUSIONS. 4-89

REFERENCES 4-96

APPENDIX A A-1
APPENDIX B B-1

Table of Contents: (Continued)

Page

CHAPTER 5: GROUND WATER AVAILABILITY PROBLEMS AND ISSUES

5.1: INTRODUCTION 5-1

5.2: GROUND WATER USE AND PROBLEMS. 5-1

5.3: LEGAL, INSTITUTIONAL, AND POLITICAL CONSTRAINTS. 5-16

5.4: SUMMARY. 5-32

REFERENCES 5-35

CHAPTER 6: PROTECTING GROUND WATER QUALITY

6.1: INTRODUCTION 6-1

6.2: SEPTIC TANKS 6-3

6.3: RUNOFF CONTROL OPTIONS 6-9

6.4: ENERGY AND MINERAL PRODUCTION. 6-16

6.5: HAZARDOUS WASTE MANAGEMENT FACILITY CONTROLS 6-21

6.6: STANDARDS FOR GROUND WATER QUALITY MANAGEMENT. 6-30

6.7: AQUIFER REHABILITATION OPTIONS 6-39

6.8: SUMMARY AND CONCLUSIONS. 6-42

REFERENCES 6-45

CHAPTER 7: WATER AVAILABILITY MANAGEMENT OPTIONS

7.1: INTRODUCTION 7-1

7.2: WATER ALLOCATION OPTIONS 7-4

7.3: PROVIDE ADEQUATE SUPPLY. 7-13

7.4: MANAGE DEMAND. 7-27

7.5: SUMMARY 7-48

REFERENCES 7-52

Tàble of Contents: (Continued)

Page

CHAPTER 8: LAND USE MANAGEMENT

8.1: INTRODUCTION 8-1
8.2: LAND USE PLANNING AND INFORMATION. 8-3
8.3: LAND USE CONTROLS. 8-11
8-4: SITING PROCEDURES FOR HIGH RISK FACILITIES 8-32
8-5: SUMMARY. 8-35
REFERENCES 8-36

CHAPTER 9: STATE AND LOCAL INSTITUTIONAL DEVELOPMENT

9.1: INTRODUCTION 9-1
9.2: OPTIONS TO IMPROVE INSTITUTIONAL CAPACITY. 9-4
9.3: ALTERNATIVE REGULATORY MODELS. 9-29
9.4: SUMMARY AND CONCLUSIONS. 9-52
REFERENCES 9-54

LIST OF FIGURES

Page

1-1: Average annual population growth rate. 1-3
1-2: Current region-wide problems: water availability. . . . 1-9
1-3: Significant water quality problems in the South. 1-10

2-1: Major rivers of the Southeast and River Basin Regions. . 2-3
2-2: Average monthly and record low monthly precipitation from 1941 to 1980 at Atlanta and Miami 2-4
2-3: Ground water resources of the Southeast. 2-6
2-4: Surface water pollution problems from point sources. . . 2-17
2-5: Surface water pollution problems from nonpoint sources . 2-23
2-6: Erosion and sedimentation. 2-24
2-7: Oil spill data for the Southeast 2-25
2-8: Ground water overdrafts and related problems 2-32

3-1: County Map of South Carolina, highlighting the Fall Line location of Lexington and Richland counties. 3-4
3-2: Preliminary map showing generalized location of five ground water recharge areas in South Carolina. 3-8
3-3: Density map of ground water contamination cases in South Carolina. 3-19
3-4: Georgetown to Wilmington case study area 3-23
3-5: Diagrammatic representation of the major aquifers. . . . 3-28
3-6: Water use patterns 3-29
3-7: Area outside Flemington landfill impacted by leachate. . 3-41
3-8: Hydrologic structures and hydrologic features of the South Florida Water Management District. 3-48
3-9: Southeast Florida showing inland extent of saltwater intrusion 1975 3-54
3-10: The Piedmont Province of Georgia 3-62

4-1: Methods of land disposal of waste water. 4-28
4-2: Density of housing units using on-site domestic waste disposal systems 4-31
4-3: Typical on-site system 4-33
4-4: Laminar flow resulting in limited contamination spread . 4-57
4-5: Potential for plumes to miss monitoring wells. 4-58
4-6: Potential for plumes to occur in strata adjacent to monitoring well screens. 4-59

List of Figures: (Continued)

Page

6-1: A cross-section of a septic tank mound system for on-site disposal 6-5

8-1: Counties and municipalities with zoning controls on agricultural land, 1980. 8-16

LIST OF TABLES

Page

1-1: Population Growth by State 1-5
1-2: Sector Earnings in the Southeast 1-6
1-3: Earnings in Manufacturing, Mining and Agriculture. . . . 1-7

2-1: Water Resource Regions in the Southeast. 2-5
2-2: Fresh Water Use in Surface Water Resource Regions of the Southeast, 1975 2-9
2-3: Water Withdrawals in the Southeast, 1975 2-10
2-4: Water Consumption in the Southeast, 1975 2-11
2-5: Water Consumption in the Southeast, 1975 and 2000. . . . 2-13
2-6: Water Use by Major Industries by Water Resource Regions, 1975 and 2000 2-14
2-7: Water Pollution Impacts from Point Source, 1977. 2-16
2-8: Significant Potential Point Pollution Sources. 2-18
2-9: Nonpoint Pollution 2-23
2-10: Significant Potential Nonpoint Pollution Sources 2-27
2-11: Water Issues Characterization Matrix 2-36

3-1: Columbia, South Carolina Metropolitan Area Housing and Population Trends. 3-5
3-2: Columbia Metropolitan Area Nonagricultural Employment. . 3-6
3-3: Ground Water Contamination Cases in Lexington and Richland Counties, South Carolina. 3-15
3-4: Summary of Statistical Data. 3-24
3-5: Employment Characteristics 3-25
3-6: Major Aquifers 3-27
3-7: Water Quality in Selected Wells. 3-31
3-8: Selected Ground Water Quality Problems in the Georgetown to Wilmington Study Area. 3-33
3-9: Selected Ground Water Contamination Cases in Brunswick and New Hanover Counties, North Carolina . . 3-34
3-10: Selected Ground Water Contmaination Cases in Georgetown and Horry Counties, South Carolina. 3-37
3-11: Population Projections 3-45
3-12: Employment by Sector, Broward and Dade Counties. 3-46
3-13: Largest County Manufacturing Firms 3-64
3-14: County Employment Summary Industries 3-64
3-15: Ground Water Use in Henry County in 1980 3-65

4-1: 1980 Industrial Hazardous Waste Generation by Industry. 4-4
4-2: Hazardous Wastes Generated by Industries Grouped by Standard Industrial Classification by State--1972 . 4-5

List of Tables: (Continued)

Page

4-3: Hazardous Waste Management Characteristics for the Southeast. 4-8
4-4: Nonpoint Souces of Ground Water Contamination. 4-24
4-5: Summary of Contamination Likely from Land Disposal of Domestic Waste Water. 4-29
4-6: Number of On-Site Disposal Systems in the Southeast-- Septic Tanks and Cesspools 4-32
4-7: Chemical Pollutants of Concern from On-Site Disposal Systems. 4-35
4-8: Major Pathogens Found in Sewage and Diseases Associated With These Pathogens. 4-36
4-9: Land Utilized by the Mining Industry in the U.S. in 1930-80, By Site and Selected Commodity 4-41
4-10: Coal Production Projections. 4-42
4-11: Mining Earnings by Industry by State--1978-2010. 4-43
4-12: Total Oil and Gas Wells Drilled. 4-44
4-13: Ground Water Pollution Cases by Pollutant Source and State 4-46
4-14: USGS and EPA Data Bases. 4-50
4-15: Ground Water Monitoring and Data Management of USGS. 4-51
4-16: Cost of Water Sample Analysis in 1974. 4-61
4-17: Monitoring Costs for Pollutant Sites in Florida. 4-62
4-18: National Interim Primary Drinking Water Standards. . . . 4-66
4-19: Public Water Supply Systems Survey of the Southeast. . . 4-68
4-20: Selected Organic Compounds Found in Ground Water 4-70
4-21: Synthetic Organic Chemicals Most Commonly Detected in Ground Water. 4-71
4-22: Injection Wells in the Southeast 4-74
4-23: Summary of Preliminary Costs for Controlling TCE in Drinking Water. 4-77
4-24: Federal Legislation Protecting Ground Water Quality. . . 4-79
4-25: State Ground Water Protection Strategies 4-83
4-26: Elements of State Ground Water Management. 4-86

5-1: Ground Water Use 1960-1980 5-3
5-2: Estimated Use of Ground Water in Southeastern U.S. in 1975 5-5
5-3: Estimated Use of Ground Water in Southeastern U.S. in 1980 5-6
5-4: Dependence of Population on Ground Water as a Source of Drinking Water, 1970. 5-10
5-5: Common Law Doctrines of Importance to Ground Water Management in the Southeast 5-18
5-6: Ground Water Use Management Capacity in the Southeast. 5-21

List of Tables: (Continued)

Page

6-1: Ground Water Quality Options 6-3
6-2: Summary: Hazardous Waste Management Facility Controls . 6-29
6-3: Examples of Classification Criteria. 6-35
6-4: Summary of North Carolina Ground Water Classifications and Standards. 6-36
6-5: Examples of Cleanup Cost for Polluted Aquifers in New Jersey 6-43

7-1: Water Availability Options 7-3

8-1: Land Use Options 8-3

9-1: State and Local Institutional Development Options. . . . 9-3
9-2: Elements of State and Ground Water Management. 9-5
9-3: Administrative Responsibility for Ground Water Management 9-8
9-4: Interest in Regionalization Among Southeastern States. . 9-22
9-5: Summary: Organizational Capacity-Building 9-26
9-6: Summary of Regulatory Models 9-50

SUMMARY

GROUND WATER MANAGEMENT IN THE SOUTHEASTERN UNITED STATES

INTRODUCTION

PURPOSE (Chapter 1)

This study of ground water management in the Southeast has three overall objectives:

- To characterize general water resource problems which could constrain development or adversely affect the environmental quality or health of residents in the region;
- To summarize the experiences of several state and local governments currently dealing with ground water problems and assess the transferability of these experiences to other areas; and
- To review policy options available to local, state, and federal officials for improving the management of ground water resources.

The study includes the eight southeastern states of Federal Region 4--Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. Current and emerging ground water problems are characterized and policy options for dealing with these problems are assessed. Audiences for the study include local, state, and federal officials with responsibility for water policy and planning; the environmental research community; and other interested parties such as industry and civic groups.

APPROACH (Chapter 1)

An interdisciplinary, policy-oriented approach was taken to accomplish four research tasks: (1) review, synthesize and integrate existing information to identify ground water problems and issues; (2) develop four site-specific case studies in Florida, Georgia, North Carolina and South Carolina; (3) convene a workshop involving interested parties and experts on ground water issues; and (4) identify and assess policy options to improve ground water management.

THE NATURE OF GROUND WATER CONCERNS

GROWTH TRENDS (Chapter 1)

The Southeast has experienced rapid growth and change over the past several decades, a trend which is expected to continue well into the future. Growth in population, industry, and resource development has created several benefits, including rising per capita incomes, relatively low unemployment rates, and improved social and cultural opportunities. However, it has also generated adverse impacts on the environment and led to conflicts over appropriate use of scarce resources. One of the major concerns is water resources, including both the impacts of growth on water quality and the adequacy of water supplies to support projected levels of growth. Ground water resources in particular are an emerging problem in the Southeast because of increasing demands, localized ground water contamination incidents, and the existence of legal doctrines and institutional infrastructures which reflect the historical abundance of water rather than a need to provide active management of the resource.

CHARACTERISTICS OF THE RESOURCE (Chapter 1)

Generally, ground and surface water resources have been abundant in the Southeast. Until recently, water problems have resulted from drought conditions or from localized pollution or overpumping. However, in some areas of the Southeast--much of Florida and the Coastal Plain--these localized ground water problems are becoming more widespread and interconnected. In addition, a complete picture of ground water quality is not available due to the lack of monitoring, especially for trace levels of toxic organic compounds. Two factors suggest that both surface and ground water problems could become more severe: increasing population and industrial growth and the inherent technical, financial, and institutional difficulties of dealing with many ground water problems.

Until recently ground water received much less attention, both nationally and in the Southeast, than other resources--surface water, air, and land. In fact, it is ironic that many of the pollution control measures to protect these other resources have increased the potential for ground water degradation by diverting wastes to the land surface or directly to the subsurface through waste disposal wells.

Several characteristics of ground water are important to understanding ground water concerns as contrasted to surface water:

- Ground water pollution is often an irreversible process. In many cases, once polluted, the slow movement and the lower level of microbial degradation to break down pollutants result in very long periods for the problems to disappear naturally. Cleaning up contaminated aquifers is often difficult and prohibitively expensive;
- Ground water pollution is a latent problem because pollutants deposited on the land may take years to leach into underlying aquifers and it may take a long time for polluted ground water to reach an active well and be detected;
- Ground water quality degradation is not visible and typically has no aesthetic impact on the public;
- Because ground water is usually of higher quality than surface water, it serves as a major source of drinking water, often with little or no treatment. Ground water is the source of drinking water for nearly 70 percent of the population in the Southeast and for virtually the entire rural population; and
- Monitoring ground water quality is expensive due to the high cost of drilling monitoring wells and analyzing samples, and the large number of samples required throughout an aquifer to obtain an accurate picture.

The remainder of this summary provides an overview of the information contained in chapters 4-9 of the report. The summary is organized into four sections:

- Ground water quality protection;
- Ensuring adequate supply;
- Land use management; and
- State and local institutional development.

The first two sections discuss specific threats to ground water and options which may be used to reduce these threats. The last two sections discuss more comprehensive approaches for managing ground water. For each section, a reference to its location in the larger report is provided.

GROUND WATER QUALITY PROTECTION

CONTROLLING INDIVIDUAL SOURCES

Potential sources of ground water pollution include: septic tanks, leaks and spills of hazardous materials, pesticides and fertilizers, improper disposal of hazardous wastes, urban run-off, mining, oil and gas production, landfills, and land application of wastewaters. Apart from the occurrence of halogenated hydrocarbons in drinking water, ground water pollution primarily results from localized activities. For example, acid drainage from coal mining in the Appalachian region of Kentucky, septic tanks along the North Carolina coast, leaks from deteriorating underground storage tanks in Florida, leaching from landfills in South Carolina, and fertilizers and pesticides in the fruit-producing areas of South Carolina are common. Of course, geological features of an area also are important determinants of pollution potential. The following sections highlight findings for several sources of ground water pollution and identify several policy options to deal with these problems.

Hazardous Wastes (Sections 4.2 and 6.5)

Hazardous wastes are an important source of ground water pollution in all eight southeastern states. This region generates about 25 percent of the hazardous wastes in the U.S., primarily from the chemical industry which is concentrated in North Carolina, Tennessee, Kentucky, and along the Gulf Coast of Alabama.

An overriding concern is the difficulty of enforcing stringent regulations for the large numbers of existing on-site disposal facilities. Some facilities may not meet EPA interim final standards and discontinue their operations, increasing the already large number of inactive and abandoned hazardous waste sites--the most dangerous sources of ground water pollution. Other on-site landfills and lagoons could leak hazardous waste into aquifers before their applications for a final operating permit are reviewed by EPA. The primary issue for ground water protection is whether the federal government is prepared to implement and enforce the Resource Conservation Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) statutes quickly and thoroughly.

Threats to ground water may also increase because:

- Small generators of hazardous waste (less than 1,000 kg per month), who are not obligated by RCRA to comply with the manifest system, may dispose of their wastes illegally rather than paying for disposal in approved facilities. Two local government options for dealing with this problem are: (1) a collection system for small generators which can reduce costs; and (2) a local manifest system to help ensure that these wastes are disposed of properly.

- Clean-up of abandoned disposal sites in the framework of CERCLA is not likely to be completed within the five year authorization period (1980-85). The large number of such sites, the hazardous nature of the waste, technical and financial constraints, and the shortage of new sites make clean-up a much larger operation than originally anticipated.

- A shortage of hazardous waste management facilities exists in the Southeast with only two commercial land disposal facilities (South Carolina and Alabama), while five of the eight states are net exporters of hazardous waste. This raises the cost of transport and disposal, thus encouraging the continued operation of on-site facilities which may not meet RCRA standards. Public opposition, the most important cause for this shortage, continues to increase and prevent the development of new sites. State and local governments can help to reduce this opposition by improved zoning and provision of needed infrastructure.

Septic Tanks (Sections 4.3 and 6.2)

Septic tanks are an important source of ground water pollution because they discharge more wastewater directly into ground water than any other source and they are the most frequently reported sources of bacterial and viral contamination. Increased use of septic tanks in the Southeast is expected due to growth in nonurban areas which have no or limited access to central sewer systems. Problems and issues include:

- High density of septic tanks can overload the capacity of the subsurface environment to remove pollutants prior to their reaching ground water;
- Improper siting of septic tanks, such as location in areas with inadequate soil types or where the drainage field is too close to drinking water wells;
- Use of chemical septic tank cleaners which contain toxic compounds; and
- Improper maintenance of septic tank systems.

For example, in New Hanover County, North Carolina, a one-half square mile area with poor soil conditions has 338 septic tanks.

Several policy options exist to address these concerns. State and local governments can update and improve their codes governing the siting, installation, and maintenance of septic tank systems. This has already been done in some areas; for example, North Carolina has revised its method of determining on-site suitability by conducting on-site inspections based upon topography, soil characteristics, ground water elevation, and depth to bedrock. Also local governments can encourage or require the use of improved septic tank technologies, including multiple drainage fields and septic tank mound systems.

Energy and Mineral Production

Extraction and processing of energy and mineral resources can impact ground water through several mechanisms, including:

- Disruption of the subsurface environment causing an increase in the dissolved solids content of ground water and exposing minerals to air and water with resulting changes in the natural geochemistry. Acid mine drainage is the best example of this impact.

- Mining and oil and gas well drilling can disrupt aquifer systems leading to changes both in quality and quantity of ground water. For example, mining can cause nearby wells to go dry and drilling can provide pathways between saline and fresh aquifers.

- Improper disposal of waste products, including coal wastes, phosphate ore wastes containing radionuclides, and brine from oil production.

Coal production is the major mining operation in the Southeast (Kentucky, Tennessee, Alabama) and acid drainage has seriously affected ground water. The Surface Mine Control and Reclamation Act has regulated coal mining operations so that ground water pollution from this source should be reduced if the regulations are enforced. However, even if they are enforced, there remains considerable technical uncertainty as to just how well the mitigation measures will work over the long term. In addition, very little attention has been given to better understanding and controlling the ground water impacts from other types of mining operations. At present, states generally rely on general water pollution control statutes to protect water resources from noncoal mining.

With respect to oil and gas drilling, regulations to protect ground water need to be reviewed and possibly upgraded. Improvements in regulatory programs should include:

- Design and performance standards for well-drilling and off-site brine disposal;

- Provision of enforcement capability; and

- Provision of means for cleaning up aquifers which are accidently polluted (e.g., pollution bonds).

Other Sources (Sections 4.3.1 and 6.3)

Ground water pollution results from a variety of other sources including:

- Leaks and spills of hazardous chemicals,

- Urban runoff, and

- Agriculture run-off.

Ground water pollution incidents from underground storage tanks have been frequent, particularly in areas where the water table is shallow such as Florida and the South Atlantic Coast. Chemical spills have also contaminated drinking water supplies. The major cause of these incidents is "poor housekeeping" by industry, airports, service stations, and farmers. Better regulations, improved technology, and better training for hazardous material handlers and transporters can reduce these problems.

Runoff from urban areas and from areas of intensive agriculture is also a problem for ground water, although less so than for surface water. Urban runoff can contain suspended solids, toxic substances (including heavy metals and pesticides), microorganisms, oxygen-demanding materials, nutrients, and oil and grease. Given the projected population growth of the Southeast and the difficulty of controlling this source, urban runoff is likely to become a greater problem in the future. Means for controlling urban runoff include technical design and maintenance activities implemented primarily at the local level, including: improving drainage and storm water handling systems; improving municipal cleaning and maintenance programs; improving vegetation cover; instituting land use controls; and requiring private sector design and maintenance standards for commercial activities.

Three agricultural practices have caused ground water contamination: use of fertilizers, use of pesticides, and animal feedlots. Fruit and vegetable farming in Florida and the Carolinas has been the cause of nitrate and pesticide contamination of ground water. "Best Management Practices" (BMPs) can be used to protect both surface and ground water; however, BMPs are new, largely voluntary, and apparently not widely practiced.

STANDARDS FOR GROUND WATER QUALITY MANAGEMENT (Section 6.6)

In addition to programs for controlling individual sources of pollution, more comprehensive approaches based on ground water quality standards can be used. Such strategies represent one of the most active areas in state policy development. Ground water quality standards include effluent standards, permits, nondegradation strategies, ambient numerical standards, and aquifer classification. In this report, aquifer classification is emphasized.

Aquifer Classification (Section 6.6.5)

Aquifer classification requires establishing a priority system for protecting aquifers. Priorities or classes could be based on current use of the aquifer (e.g., drinking water source), aquifer yield, natural quality of the ground water, vulnerability to pollution and alternative sources of water in the area. Classification systems contrast with other management approaches that uniformly protect ground water such as statewide nondegradation strategies. Even without formal classification systems, this approach is often practiced by emphasizing drinking water sources rather than saline aquifers, for example.

At least eleven states have developed classification systems. Florida has established three classifications: potable/single source, potable/nonsingle source, and nonpotable. Criteria have been drafted for any discharge into the two potable classes to prevent established water quality standards from being exceeded. These same criteria may not necessarily apply to the nonpotable class if it is determined that no danger to health, safety or welfare of the public exists. A local aquifer management program developed by New Hanover County, North Carolina contrasts with many other approaches in that the emphasis is placed on protecting recharge areas and aquifers sensitive to contamination rather than protecting use categories or existing quality.

The principle advantages of the classification systems are that management priorities are established and site-specific differences in environmental protection and economic growth are recognized. The flexibility of classification is often very desirable since enforcement resources are always limited.

One weakness of classification systems is that they require a solid information base and a technically competent administrative system, although technical precision may not be essential to achieve some degree of effectiveness. Classification systems also may commit some aquifers or parts of aquifers in low quality classes to a new, permanently contaminated status. Unlike surface water classification, future changes in use or quality may be difficult or impossible to accomodate, because ground water takes decades or centuries to recover naturally.

WATER TREATMENT AND AQUIFER REHABILITATION

The previous discussion identified measures to prevent ground water pollution. Other alternatives for dealing with ground water quality include:

- Rehabilitation of contaminated aquifers, and
- Improved treatment of drinking water supplies.

Aquifer Rehabilitation (Section 6.7)

Rehabilitating a polluted aquifer can include any or all of the following steps: (1) abatement of pollutants from further spreading using either physical (e.g., subsurface barriers) or chemical means; (2) clean-up of polluted ground water, either by removing the pollutant(s) in situ or on the surface; and (3) restoration of the aquifer to its original condition, including clean-up and recharge of the aquifer. Rehabilitation plans will be heavily influenced by site-specific characterisitcs. Because experience with rehabilitating aquifers is limited, reliable information on effectiveness and costs is scarce. Although a few specific applications of abatement measures can be found, frequently information about these experiences will not be disclosed because the case is subject to legal action.

Rehabilitation is constrained by several political, economic, and technical factors. It is often costly, ranging from hundreds of thousands to millions of dollars. Polluters are frequently unwilling or unable to provide adequate funds, and Superfund sources are limited. Many rehabilitation measures are technically unproven, and their use in some circumstances may be constrained by the Underground Injection Control program of the Safe Drinking Water Act.

Drinking Water Treatment (Section 4.5)

Ground water also can be treated prior to domestic use in order to protect human health. Treatment may be a particularly important option because: (1) ground water supplies 67 percent of the total drinking water in the Southeast and 98 percent in rural areas; (2) currently, ground water is often given little or no treatment; and (3) low levels of toxic organic compounds have been detected in large numbers of water supply wells. In a sample of water supply wells in six southeastern states, trace levels of nine volatile organic chemicals were detected; chemicals were found in as few as 5 percent of the wells in Kentucky to as many as 50 percent of the wells in Florida.

Key issues related to drinking water treatment compared to other options for ground water protection are:

- Drinking water standards: although more than 700 chemicals have been identified in drinking water supplies, only 16 maximum contaminant levels have been established under the Safe Drinking Water Act;

- Health effects: the long term health effects of exposure to low levels of synthetic organic chemicals is poorly understood; massive research efforts would be required to establish a scientific basis for setting maximum contaminant levels;

- Regulatory programs: many gaps exist in existing regulatory programs and states generally do not have sufficient resources to adequately enforce drinking water quality standards; and

- Monitoring and treatment costs: monitoring and analysis costs at least $200 per sample for some organic chemicals. Cost and effectiveness of treating synthetic organics varies considerably depending on the scale of the application, the technology chosen, and the pollutants to be removed.

ENSURING ADEQUATE SUPPLY

In general, the Southeast is not a region where water availability should be a problem if resources are managed properly. Surface water is abundant, ground water resources are widespread, and rainfall is plentiful. Nevertheless, some areas are experiencing water availability problems. This is particularly true for much of Florida and the Atlantic coast. Although availability problems generally are localized in nature, they are becoming more widespread and more severe. In the future, existing supply systems will face increased stress from irrigated agriculture, new and expanding industries, population growth, and water quality problems that limit the uses of the available water.

GROUND WATER USE PATTERNS (Sections 5.2.1)

The use of fresh ground water in the Southeast increased by 160 percent between 1960 and 1980--from 3.2 to 8.4 billion gallons per day (bgd). Except for withdrawals for hydroelectric or thermoelectric power generation, ground water accounted for 41 percent of the fresh water supplies of the southeastern states in 1980. Ground water withdrawals increased in every state except Alabama between 1975 and 1980. Florida, Georgia, and Mississippi use the most ground water of the states in the Southeast and are the most dependent on it as a source of supply. Florida alone accounts for 44 percent of the ground water used in the Southeast.

The most important use of ground water in the Southeast is for drinking water. In 1970, 67 percent of the population in this region relied on ground water as their source of drinking water. In Florida and Mississippi, ground water accounted for approximately 90 percent of the total drinking water supply. Virtually all of rural drinking water supplies come from ground water sources.

Between 1975 and 1980, considerable increases took place in the amount of ground water withdrawn for public, rural, and irrigation uses. Although self-supplied industrial uses decreased slightly, ground water for irrigation has become much more important. Mississippi (87 percent), Georgia (66 percent), Florida (53 percent), and Tennessee (53 percent) are the most dependent on ground water for irrigation.

OVERDRAFT PROBLEMS (Section 5.2.2)

In the next 10 to 20 years, ground water withdrawals are likely to increase in response to population growth and economic development. The unconstrained use of aquifers in some areas of the Southeast has already resulted in ground water quality and availability problems. These include:

- Degradation of Ground Water Quality: the intrusion of sea water or saline or brackish water from inland aquifers is one of the most serious results of overpumping. This has been a particular problem in the high pumping areas along the Atlantic Coast, such as the Biscayne Aquifer that serves as the sole source of potable water for the Miami, Fort Lauderdale, Palm Beach area. Heavy water-using industries in the Brunswick, Georgia area and pumping for irrigation and livestock watering in the Georgia portion of the Suwannee River Basin has resulted in the upward migration of highly mineralized water;

- Lower Water Tables and Diminished Supply: in many states pumping rates are not regulated; they are guided primarily by the cost of drilling a well and raising the water. Excessive withdrawals can lower the water table to a point where it is no longer economical to pump the water. Overpumping from wells in the Georgetown, South Carolina area has resulted in a reduction of the water level of the Black Creek Aquifer of 50 feet in some locations. Lowered water tables can result in increased costs for bigger pumps using more energy, the need to locate alternative water supplies and increased competition for available water; and

- Subsidence: overpumping can result in a drop of several feet in the ground surface over a large area. This can damage structures, cause flooding in low-lying coastal areas, and lead to the development of fissures and sinkholes that can allow the entry of contaminants into the aquifer. Subsidence is the most serious in Florida, both in terms of frequency and severity. Although subsidence problems in Georgia are not nearly as severe or widespread as in Florida, they have been occurring more frequently in recent years.

IMPROVING WATER ALLOCATION SYSTEMS (Sections 5.3 and 7.2)

If states are to improve their capacity to respond to water use problems, they may need to modify existing laws and institutional arrangements which were designed to manage abundant rather than limited water resources. Common law docrines and statutory permit systems are the primary mechanisms currently used for allocating both surface and ground water in the southeastern states. At least five common law doctrines affect allocation decisions:

- Riparian doctrine;
- English rule of absolute ownership;
- American rule (or reasonable use);
- Correlative rights; and
- Prior appropriation.

Comprehensive permitting systems have also been established by statute in many states to facilitate the state's role in allocating water. Although water law in the Southeast has been commended for its respect of the property rights concept and lack of government involvement, states need to modify those sections of their laws which are particularly restrictive, such as requiring use of water on riparian or overlying land.

Modification of Water Law

Each state differs in the degree to which its water allocation framework has been stressed by ground water availability problems. Florida, for example, made major changes in its water management system in the early 1970's in response to both severe floods and droughts. In contrast, South Carolina, which has never had a court case over a ground water conflict, is in the initial process of evaluating the adequacy of its water allocation laws.

One issue with existing frameworks is uncertain liability, which means that water rights are not defined in sufficient detail to identify available remedies for injured parties. The correlative rights doctrine, which thus far has been applied in Florida and California, uses the concept of mutual accountability or liability among ground water users sharing a common aquifer. Alternatives for clarifying liability within the existing legal doctrines include:

- First users principle--gives the superior claim to the first user in an area;
- Priority use rule--establishes a statutory preference system; and
- Comparative clause rule--provides liability in proportion to damages caused by all other users.

Riparian, reasonable use, and correlative rights water doctrines can restrict water transfers across watersheds or even to nonriparian or nonoverlying land. Statutory amendments can be enacted to allow transfers to uses on other than riparian or overlying land so long as the uses meet the basic test of reasonableness. States may also provide for the creation of public water districts or cooperatives which may transfer water.

Differing legal doctrines for surface and ground water constrain effective planning and management of water resources. This situation could be improved by legal changes to recognize the relationship between surface and ground water. Without such statutory authority, courts have not had a basis for including potential ground water impacts from surface water development, for example, in resolving conflicts among users. Such legal changes are also important to facilitating conjunctive management of surface and ground water.

Permitting (Sections 5.3 and 7.2.2)

Permitting systems require users to seek governmental approval in the form of a permit or license to withdraw. Permits can serve primarily as an information gathering device to provide a state with a picture of use patterns. Permit systems also can serve as a planning and management system, replacing existing allocation doctrines with administrative approval and coordination of all water rights. Six states in the Southeast have some form of permitting system: Florida, Georgia, Kentucky, Mississippi, North Carolina, and South Carolina.

Many states outside the Southeast have also adopted some type of permitting system, indicating the potential value of this approach. Because permits are issued for specified periods of time and for a quantified allocation, they provide reasonable security of supply for well owners and give administrators flexibility in responding to changing needs. It can also be a valuable conservation management tool during droughts. However, without clear guidelines for issuing or denying permits, this approach could result in inefficient or overly discretionary allocation of water among competing uses.

STRUCTURAL ALTERNATIVES (Section 7.3)

Water shortages can take place for many reasons, including: the need to satisfy the heavy demand of a growing population and economic development; poor quality water which is limited in its uses; droughts and seasonal dry periods; and the uncertainties associated with depending on supplies from outside the area of use. Although no single structural option for ensuring supply will be sufficient by itself, combinations of options along with strategies for managing demand can help reduce current and future stresses on ground water systems. Five structural alternatives have been reviewed in this report:

- Expanded use of surface water to supplement ground water withdrawals or to replace ground water as a source of supply;
- Well-field development and management to increase reliability of supply, reduce costs, and decrease environmental impacts;
- Desalination, particularly along the Atlantic Coast, can help protect against crises conditions or droughts;
- Subsurface storage and retrieval can be used in some areas to increase supply during dry seasons or in periods of particularly heavy demands; and
- Artificial recharge of ground water by percolation or injection.

In this report, artificial recharge is emphasized.

Artificial Recharge of Ground Water (Section 7.3.5)

Artificially recharging a ground water system through percolation or injection can reduce and occasionally reverse declining ground water tables, increase well yields, improve water quality, protect aquifers against the intrusion of sea water or underlying brackish water, and reduce land subsidence. The water for recharge generally comes from storm water runoff, local or imported surface water, or treated wastewater.

The major disadvantage of artifical recharge is concern about undesirable health impacts--especially when wastewater is the source of recharge water and potable use is expected. Many studies are underway to determine the potential health impacts of ground water recharge operations; positive results from these studies will be necessary before widespread use of this option is likely to make a major contribution to potable supplies.

Some methods of artificial recharge can result in enhanced water quality. Percolation and subsurface flow can remove some contaminants and retard the movement of others and, thus, reduce the health risk of potable use. Depending on the characteristics of the aquifer and the contaminants involved, the level of treatment required after withdrawal could be reduced.

Artificial recharge is practiced in many parts of the United States; approximately 300 projects operate in areas of California where ground water has been extensively exploited. Generally, recharge for agricultural use is widely accepted as safe and cost-effective. This option may be well-suited to those areas of the Southeast where saltwater intrusion is a major concern or where ground water is the major source of supply and demands are heavy.

MANAGING DEMAND (Section 7.4)

The abundance of water throughout the Southeast and the availability of federal funds to develop surface supplies have impeded the development of management tools designed to reduce or restructure water demands. Adopting a demand modification approach to water management requires a change in the way water typically is viewed; that is, policymakers and the public would have to recognize water as a valuable but limited resource. Because of rapid growth and development as well as periodic summer droughts, localized areas of the Southeast have begun to experience shortages of water. Some of these areas have responded by using options such as conservation and pricing schemes to control demands. The South Florida Water Management District, for example, is implementing an extensive set of conservation policies to curb demand. Experiences with conservation and economic incentives as demand management tools in other parts of the United States generally have been positive.

Conservation (Section 7.4.1)

Conservation can reduce short-term demand and help ensure supplies for long-term growth. It also can make a substantial contribution to improved water quality by reducing the amount of discharge. Viable conservation alternatives are available for residential consumers, business and industry, and agriculture.

Conservation efforts for domestic users include: media campaigns to change use patterns, the installation of water meters, use of water-saving devices on shower heads and toilets, leak detection, increased unit costs for water, and mandatory reduction of exterior uses. For example, Georgia and Florida already require water-saving plumbing devices. Some businesses and industries have responded to water quality regulations and increasing costs by recycling and reusing process water. Farmers can control the rate, amount, and timing of water while still improving crop yields. Current agricultural practices include: using new irrigation techniques such as low-energy precision application systems, switching to low moisture crops, and using computerized information systems on local soil moisture and weather conditions.

Technical options, such as wastewater reuse, use of water saving devices and appliances, improved irrigation methods and crop switching, can help save water and reduce stress on drinking water. Conservation by domestic and commercial users can delay the need to expand the capacity of municipal water supply systems and treatment facilities. Public education programs can facilitate community understanding of water availability and quality problems. In some cases, this can help to reduce conflicts and perhaps avoid more stringent control options.

Pump Taxes and Pricing Alternatives (Sections 7.4.2 and 7.4.3)

Pricing water can help to provide information about both supply and demand for the water resources in an area and encourage users to carefully consider the value of alternative uses. Water supply system managers can use pricing schemes to achieve conservation goals. Ideally, these water prices would incorporate information about demand and cost changes over time, location and groups of users. In practice, pricing policies also incorporate public concerns over the fairness of varying rate structures and their impact on business and industry.

Studies of pricing policies in the U.S. have concluded that they have almost never been used primarily to control demand. However, this has been changing recently, especially for areas where additional water supplies are very costly to develop or are not available. Water demand has been shown to be sensitive to price changes, although it does vary among users--residential and small business users have the most flexibility while large industrial users have relatively fixed water demands. Experiences of utilities using price strategies to reduce demand appear to be successful, especially where accompanied by public education programs. Key constraints to pricing options in the Southeast include the lack of meters in homes and on wells.

LAND USE MANAGEMENT

RELATIONSHIPS BETWEEN LAND USE AND GROUND WATER (Section 8.1)

Ground water quality and availability problems are frequently related to either past or present land use practices. Land uses can affect the amount of ground water withdrawn, and recharge available, or allow pollutants to enter the subsurface environment. Adverse impacts are often created by the combined effects of many independent land use decisions, and impacts caused by one land user are sometimes felt by adjacent or distant land users. As a consequence of these relationships, ground water availability and/or quality problems can be addressed by improved land management.

Generally, land use management serves two broad objectives:

- Prevent Changes: Land uses that adversely affect ground water can be discouraged from locating in sensitive areas or can be regulated by standards that mitigate their impact. For example, septic tanks can be prohibited from some areas or can be required to meet standards which reduce their pollution potential; and

- Protect Users: In areas with existing or likely ground water problems, land users that would be affected by poor ground water conditions can be protected by standards designed to mitigate impacts. For example, residences dependent on shallow, water table wells can be discouraged from building near a landfill or can be required to drill deeper wells.

COMPREHENSIVE LAND USE PLANNING (Section 8.2)

Traditionally, land use planning has been exercised at the local-level, focusing on socio-economic concerns. However, for ground water problems a state perspective which incorporates comprehensive land use planning may be needed because land use affects so many values besides ground water. In some areas of the U.S. (e.g., Florida, Vermont, and Oregon), there has been a move towards statewide programs of comprehensive land use planning and control that make explicit provision for resource and environmental concerns. However for a large majority of local areas and states, land use planning faces strong opposition because it requires direct control of economic activities.

The limited or single-purpose nature of many federal problems and the lack of coordination among them have resulted in fragmented programs at the state level. Also, land use plans under many of these federal programs rarely deal effectively with ground water. However, some federal legislation has encouraged land use planning for sensitive lands, such as flood plains, coastal zones, and wetlands, which are frequently important to ground water.

There are several obstacles to using comprehensive land use planning in the Southeast. These include:

- Intervention in private land use decisions is strongly resisted.
- A significant financial commitment, in addition to an extensive data/information base, is required.
- Because of the need for both centralized authority and a high level of local cooperation, implementation is often a major problem.

However, the experiences of Florida, Georgia, and North Carolina, although limited in scope, suggest state comprehensive land use planning is not impossible in the Southeast. Georgia, for example, passed the Metropolitan River Protection Act which requires all construction within 2000 feet of a watercourse to comply with a coordinated land and water use plan.

LAND USE CONTROLS (Section 8.3)

Controls over the use of land to achieve ground water management goals have been implemented by some state and local governments in the Southeast. Zoning, design standards, performance standards, land purchase, and financial use control incentives have been adopted.

When politically feasible, land use controls are comparatively easy to implement and enforce. Political opposition, especially in rural areas, has limited their widespread adoption. Land use control options include:

- Zoning, one of the most common forms of land use control, can be especially effective in controlling industrial uses and population density;
- Design standards, such as building and septic tank codes, can be effective but require extensive enforcement;

- Performance standards that define maximum permissible input of land uses are more flexible than design standards;

- Purchasing land or land rights may be applicable for the most valued resource areas where extensive public benefit is perceived. This may occur when ground water resources are closely associated with parklands, for example; and

- Financial incentives may be used to assist landowners with implementing good management practices.

Land use controls are especially effective in conjunction with related groundwater management techniques such as aquifer classification programs and discharge controls. Land use controls may be particularly useful in intensively used areas or in sensitive areas such as recharge zones.

STATE AND LOCAL INSTITUTIONAL DEVELOPMENT

In most southeastern states, awareness of the need to improve ground water management capacity has increased dramatically in the past few years. This has been particularly evident among professional water resource managers at the state executive level. There is generally much less awareness of ground water management needs among the general public and at the state legislative level. As stresses on ground water continue, more attention will be given to alternatives for enhancing regulatory and institutional capacity. Several options to enhance institutional capacity and to develop new regulatory systems have been assessed in this report.

INSTITUTIONAL CAPACITY BUILDING (Section 9.2)

Several ground water problems have led to increased attention to the need for improving institutional capacity. These include:

- Legal systems which create barriers to active management;

- Over-reliance on courts as conflict resolution mechanisms;

- Increased competition among agricultural, industrial, and municipal users;

- The economic and environmental significance of emergencies, including droughts and contamination from toxic substances; and

- Increased awareness of the need to link growth policy to natural resource policy.

Five options for improving state and local institutional capacity for managing these problems have been assessed: integrating ground water quality and use management, conjunctive use management, emergency response mechanisms, designation of critical use areas, and cooperative supply systems.

Integrating Quality and Use Management (Section 9.2.2)

Historically, ground water quality has been a separate policy area from ground water availability management--they have represented different problems and different sets of interests. As ground water use and problems have increased, so has attention to the need to develop integrated management strategies. Integration could be accomplished by creating a new agency, consolidating authority in an existing agency, or developing interagency coordination mechanisms.

This option will face strong resistance in many states, particularly from existing users who could be threatened by reorganization. However, integrated administration has several advantages;

- The inherent linkages between quality and use would be recognized;

- Users would be better able to meet regulatory requirements; and

- Administrative efficiency could be increased.

Several southeastern states have recently reduced the fragmentation of ground water administration, and Georgia has developed an integrated approach which incorporates a one-stop siting process. Further integration can be expected during the 1980s; Georgia's experience should be useful for many other states.

Conjunctive Use Management (Section 9.2.3)

Surface and ground waters are closely related; institutional capacity to manage water resurces can be enhanced through integrated or conjunctive management of the two resources. For example, during periods of low surface flow, which very often coincide with peak seasonal demand, ground water can be used to augment surface water; during peak runoff periods artificial recharge techniques can be used to increase ground water supplies for use during dry periods.

For this option to be effective, a comprehensive definition of conjunctive use is required; it should refer to the integration of surface and ground water use to increase the reliability and efficiency of the supply system and the development of active management programs to preserve and protect surface and ground water. If defined comprehensively, conjunctive use can have several advantages:

- Increased recognition of the relationship between surface and ground water;
- More efficient use of limited water resources;
- Decreased surface storage and distribution requirements; and
- Increased reliability of supply.

Similarly to integrating use and quality management, "comprehensive" conjuctive use will face several barriers: legal statutes which treat surface and ground water separately, resistance from some current users, and political and financial constraints to administrative reorganization. However, North Carolina and Florida use conjunctive management for designated areas. As demands and stresses on ground water increase, this management tool is likely to be adopted more pervasively in the Southeast.

Emergency Response Capacity (Section 9.2.4)

Even with active water resource management programs, shortages caused by drought and/or overuse can occur. Advance preparation for water shortages rather than ad hoc responses can reduce economic and social costs. North Carolina, South Carolina, Georgia, Mississippi, and Florida have recognized the need to develop the capacity to manage water shortages and in some cases these programs seem quite adequate.

Emergency response programs should be flexible in considering the uncertainty of public and well owner cooperation and the extent of the shortage. They also should contain "trigger mechanisms" to automatically initiate emergency plans and adequate enforcement mechanisms if predetermined threshold levels are reached. The recent water shortages in several southeastern states and the growing recognition of the importance of reliable water supplies for attracting new economic development should make emergency response planning a feasible and valuable ground water management option for the Southeast.

Critical Use Areas (Section 9.2.5)

Designation of critical (or capacity) use areas is a management approach which concentrates regulatory controls on areas where overuse of ground or surface water threatens the capacity of the resource to renew itself. State or local intervention can include limits on the rate of withdrawals, permitting, well spacing requirements, and land use management. Florida, North Carolina, South Carolina, and Mississippi in the Southeast and twenty other states nationwide have developed the capacity use area approach.

Designation of capacity use areas is one of the most politically feasible management options, largely because of the flexibilty it affords to develop strategies which are suited to local areas under stress. In part, it represents a first-step in controlling ground water problems. However, it is also a reactive approach which essentially ignores the need to anticipate emerging problems. Because it represents a case-by-case or area-by-area approach to supply problems it is likely to be a barrier to more comprehensive and integrated approaches. The capacity use approach has not been very successful in the Southeast; for example, it was tried and eliminated from Georgia's water management approach.

Cooperative Supply Systems (Section 9.2.6)

Most of the Southeast is characterized by large numbers of small water supply utilities. Cooperative supply systems are designed to enhance water supply management by increasing cooperation among water supply utilities, either through informal agreements among districts or by unification and consolidation. This option offers several advantages:

- Better balance between the location of water resources and consumer needs;

- Reduced inequity in financial resources among water districts;

- Less jurisdictional conflict; and

- Improved management of supplies and water distribution systems.

Obstacles to implementing cooperative supply systems include opposition from districts favoring autonomy, unwillingness of stable and efficient utilities to assume the inadequacies of another utility, lack of communication, and physical design inconsistencies among systems. Nevertheless, several areas in the Southeast have adopted it and one recent survey indicated that in a sample of 94 utilities, 36 percent had studied or were studying the option. Although this option is much more limited in scope than many management approaches, it could be useful for localized problem areas, especially those wanting to avoid a stronger state role in ground water management.

ALTERNATIVE REGULATORY MODELS (Section 9.3)

The overall structure and administration of ground water policy is also receiving increased attention in many states. Particularly important questions in this regard include the comprehensiveness of the regulatory approach, the level of centralization, and relationships among state and local levels of government. To give a better perspective on these questions, three regulatory models were reviewed, based on the experiences in Arizona, Nebraska, and Florida. These models were chosen because they represent recent attempts to manage ground water, they range from very centralized to decentralized approaches, and they represent reform which ranges from very comprehensive to incremental.

Description

State regulatory systems for ground water reflect several characteristics of the state--the severity of its problems, historical relationships among units of government, the nature of competing demands for the resource, public awareness, the political commitment to reform, and unique events or crises in the state. Variations in these factors led Arizona, Nebraska, and Florida to develop very different ground water policy systems;

- The Arizona Model, created in 1980, reflected a long history of ground water overdraft, nonmanagement of the resource, and increased competition from municipal and industrial interests. In 1980, the state developed a management system which concentrated authority in the State Department of Water Resources. Five Active Management Areas were designated, reflecting areas with the most severe problems. The state was granted virtually complete regulatory authority, strong management tools such as mandatory conservation, and powerful enforcement tools.

- The Nebraska Model, created in 1975, reflected a gradual process of problem-recognition, rapidly increasing needs for irrigation in some parts of the state, and gradually increasing competition. Nebraska developed a decentralized approach, granting primary management responsibility to 24 Natural Resource Districts. Management tools can include land use controls and mandatory conservation. State agencies are responsible for providing oversight and collecting data.

- The Florida Model, created in 1972, reflects the state's unique geohydrology and long histories of ground water problems and local autonomy. Florida granted the Department of Environmental Regulation the authority to control ground water quality, while five Water Management Districts were granted nearly autonomous authority to regulate ground water quality and to raise taxes to support the regulatory program. Several coordination mechanisms were created to facilitate interaction between the state and the Districts, including creation of regional offices of the Department of Environmental Regulation.

Regulatory and Administrative Issues

The Arizona and Florida models both exert strong, active management approaches to ground water. They are also fairly comprehensive in reforming the legal and administrative structure and in developing specific management strategies. The Arizona Model appears to be advantageous if the goal is to maximize state control over ground water use allowing the state to determine fundamental issues of how water resources will be allocated among competing demands. Similar to the Arizona Model, the Florida Model provides a comprehensive, active management approach. In contrast, by balancing state with local authority it is somewhat less suitable for encouraging substantial changes in existing uses.

The Nebraska Model is much less comprehensive; it would be more suitable for states in which ground water problems are developing at a gradual pace. Local management districts have even more autonomy than in the Florida Model, since the Nebraska Model does not include a strong, centralized state agency and fewer formal coordination mechanisms are established between the state and local districts.

These models provide valuable comparisons on questions currently being raised by several southeastern states--the degree of local autonomy, state-local coordination, and integration of quality and use management. While each state will require different solutions to these questions, the experiences of Arizona, Nebraska, and Florida suggest:

- With the exception of some local districts in Florida, it appears to be unusual for local governments to have the political or institutional capacity to exert strong management control. Thus, the more decentralized models appear to favor existing water users over new users;

- The effectiveness of any regulatory system will depend in part on the success of intergovernmental coordination mechanisms. Few states have well-developed coordination mechanisms; although Florida has an innovative structural approach, many questions remain about its overall effectiveness in coordinating programs among various levels of government; and

- Failure to integrate quality and use considerations can create several constraints to effective management.

CHAPTER 1

WATER AND GROWTH ISSUES IN THE SOUTHEAST

1.1 INTRODUCTION

The Sunbelt states have experienced rapid growth during the past few decades--for example since 1960 energy consumption and manufacturing employment have grown at a faster rate than in any other region and, along with the West, the South has had the fastest rate of population growth.[1] Growth in most major sectors--energy, manufacturing, agriculture, and population--are projected to continue at rates faster than the national average well into the next century.

This growth raises several concerns about whether Sunbelt states can continue to gain the benefits of development while minimizing negative impacts on natural resources, social and economic systems, and the quality of life. One of the major concerns is water resources, including both the impacts of growth on water and the adequacy of water to support projected levels of growth. While water resource concerns are one of the key emerging issues facing the Southeast, the institutional capacity for dealing with many of these concerns will need to be enhanced. In part, this can be attributed to the historical abundance of water in the Southeast and the lack of major events or conflicts over water quality. However, concern for water resources is increasing throughout the region and considerable attention is now being paid to strategies for protecting and managing water resources.

The purpose of this report is to address water resource concerns in the Southeast, emphasizing current and future ground water issues.[1] Both ground water availability and quality problems are discussed, based in part on an analysis of four case studies of locations in the region which are likely to face stress on ground water resources. In addition to identifying ground water concerns, the report is intended to produce an inventory of policy options for reducing ground water conflict and to identify options which may be particularly applicable to emerging problems in the Southeast.

---

[1] In this report, the "South" and the "Sunbelt" refer to the 13 states of Federal Region 4 (Kentucky, Tennessee, Mississippi, Alabama, Georgia, Florida, North Carolina, and South Carolina) and Region 6 (Louisiana, Arkansas, Oklahoma, Texas, and New Mexico). The "Southeast" refers to the eight states of Region 4.

The remainder of this chapter provides an overview of water and growth in the Southeast. Section 1.2 outlines population and industrial growth in the Southeast. Section 1.3 describes general water resource concerns, the rationale for focusing on ground water issues, and the specific purposes and scope of the study. A final section (1.4) discusses the organization of this report.

1.2 GROWTH IN THE SOUTHEAST

The recent rapid growth of the South has been determined by the ability of the region to attract manufacturing capacity and people. While the the relative importance of industry and population as the causes of regional growth is not clear, the overall explanation for the for the South's rapid growth is that many attractive features have come together in recent years. Important features attracting people include climate, recreational opportunities, availability of less crowded, nonurban settings, lower cost-of-living and taxes, and a decline in regional disparities in income, education, and cultural amenities (see Science and Public Policy 1983, ch. 2).

Characteristics which attract industrial growth include plentiful labor supply, traditionally low wages, and low levels of union activity. These advantages have been particularly attractive to firms manufacturing established products with relatively few technical, managerial, and professional inputs. The movement of these kinds of firms to the South has been facilitated by development of a large regional market, construction of the southern interstate highway system at a time when much freight was shifting from the rails to the highways, and the economic benefits of self-sustaining, concentrated industrial centers.

---

[1] This report is the second phase of a larger project, An Integrated Environmental Assessment of the Southern Region. This "Sunbelt Project," begun in September 1980, was intended to identify forces creating change in the Sunbelt and to anticipate long-term concerns with this growth. The first product of the Sunbelt Project was the Environmental Status Report (Science and Public Policy 1983).

The following section provides a brief overview of growth in population and industrial earnings. This discussion is intended to suggest a few of the key changes likely to occur and the areas likely to experience these changes.[1]

1.2.1 Population Growth

For much of this century, the Southeast experienced slow population growth; for example between 1940 and 1970, all states except Florida grew at a slower rate than the national average. However, beginning in the late 1960's, population growth began to increase dramatically and surpass national averages. As shown in Figure 1-1, the average annual growth rate from 1970 to 1980 for each state in the Southeast exceeded the national average. This growth is projected to continue through the year 2010. According to recent projections of the Bureau of Economic Analysis, the Southeast is projected to have a 30 percent population growth, compared to the U.S. average of 20 percent (U.S. Bureau of Economic Analysis

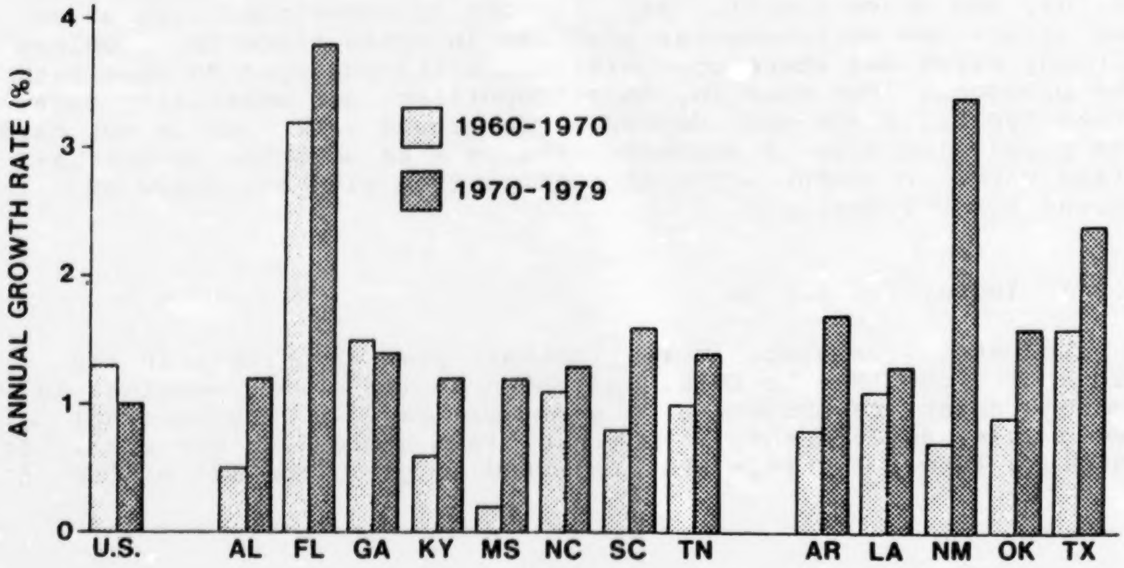


Figure 1-1: Average annual population growth rate.

Source: U.S. Bureau of Census 1980, 12.

---

[1] This material is taken from Volume I (chapters 3 and 4) of the Environmental Status Report (Science and Public Policy 1983).

1980). Florida has been by far the fastest growing state, experiencing a 44 percent growth from 1970 to 1980. Florida is projected to have a 45 percent growth rate from 1980 to 2010, more than twice the national average (see Table 1-1). Alabama is the only state in the Southeast projected to grow at a rate slower than the national average (Science and Public Policy 1983, ch. 3).

In addition to the overall rate of growth, the distribution of growth can be important. The Southeast is experiencing substantial growth in metropolitan and nonmetropolitan counties.[1] Metropolitan areas, particularly suburban counties, currently are growing at a slightly more rapid rate than nonmetropolitan areas, and are receiving almost two-thirds of the population influx. Nonmetropolitan areas also are growing rapidly, with most of the growth in counties with urban centers of 2,500 or more. Population growth in the Southeast is generally widespread rather than concentrated in a relatively few states or areas within those states.

Growth often has different environmental consequences in metropolitan than in nonmetropolitan areas. Rapid growth in metropolitan areas may exacerbate existing problems created by large concentrations of people: high demand for water; extensive surface modification and paving; and large volumes of sewage; industrial wastes, and storm runoff. Rapid growth in nonmetropolitan areas may create new environmental problems in areas where few problems already exist and where communities are ill-equipped to cope with the problems. For example, nonmetropolitan, and especially rural areas typically are more dependent on ground water and do not have the population size or concentration to make sewering or centralized water treatment and distribution from either surface or ground sources feasible.

1.2.2 Industrial Trends

Industrial earnings in real dollars grew 43 percent in the Southeast from 1969 to 1978. As shown in Table 1-2, earnings in the Southeast are projected to grow more rapidly (209 percent) between 1978 and 2010 than in the U.S. as a whole (167 percent). In absolute terms, earnings are projected to grow from 123 billion to

---

[1] Metropolitan counties have at least one city with 50,000 people. Nonmetropolitan counties are defined as all other counties. Within the nonmetropolitan class, rural counties have no urban center of more than 2,500 people.

TABLE 1-1: POPULATION GROWTH BY STATE
(percent)

State	1970-1980	1980-2010
Florida	44	45
South Carolina	20	29
Georgia	19	23
Tennessee	17	33
North Carolina	16	26
Mississippi	14	28
Kentucky	14	24
Alabama	13	15
U.S. Average	11	21

381 billion dollars.[1] All sectors except agriculture, forestry, and fisheries are expected to grow more rapidly in the Southeast than in the U.S. Among the basic sectors (manufacturing, mining, and agriculture) which supply the impetus for growth in the remaining service sectors, earnings in manufacturing and mining are projected to grow much faster than the U.S. average. Based on this growth rate and absolute earnings, manufacturing appears to be the key driving force behind industrial growth in the Southeast. However, agricultural earnings are growing very fast in some southeastern states (particularly Tennessee, Florida, and Georgia), as is the use of irrigation for agriculture.

Table 1-3 identifies growth rates of industries within the manufacturing, mining, and agricultural sectors. Based on 1978 earnings, the six largest industries in the Southeast were machinery, textiles, chemicals, food and kindred products, transporation equipment, and apparel. Of these, machinery is projected to be one of the fastest growing industries through the year 2010, with an increase of 326 percent. Other industries projected to have particularly rapid growth rates are: instruments (426 percent, coal mining (399 percent), petroleum refining (360 percent),

---

[1] Earnings figures are expressed in terms of constant 1972 dollars. Data are based on the Regional Economic Projections of Economic Analysis, U.S. Department of Commerce (see Science and Public Policy 1983, ch. 3). The major assumptions of these projections are that historical trends in rates of change will continue but decelerate; no significant policy changes will occur; and resources will be made available for development as needed (pp. 3-1 to 3-3).

TABLE 1-2: SECTOR EARNINGS IN THE SOUTHEAST
(millions of 1972 dollars)

Sector	1969	1978	1990	2000	2010	% change 1978-2010 Region 4	% change 1978-2010 U.S.
All Industry	86,137	123,318	205,565	285,002	380,641	209	167
Agriculture, Forestry, Fisheries	3,708	4,260	4,763	5,539	6,522	53	59
Mining	625	1,562	3,523	4,815	6,206	298	171
Construction	5,823	7,743	13,162	18,080	24,030	210	172
Manufacturing	23,169	31,077	51,518	71,437	95,310	207	121
Transportation, Communication, Public Utilities	5,689	9,446	16,427	23,278	31,548	234	177
Wholesale Trade	5,121	8,054	13,333	18,158	23,913	197	151
Retail Trade	9,465	13,030	21,447	29,564	39,265	201	154
Finance, Insurance, Real Estate	4,174	6,523	11,934	17,249	23,687	263	204
All Service	12,306	18,725	35,201	51,896	72,289	286	237
All Government	15,674	22,311	33,337	43,780	56,314	152	128

Source: U.S. Bureau of Economic Analysis 1980.

TABLE 1-3: EARNINGS IN MANUFACTURING, MINING, AND AGRICULTURE (millions of 1972 dollars)

Sector (SIC codes)	1969	1978	1990	2000	2010	% change 1978-2010
Manufacturing Durables	10,318	14,752	26,830	38,740	52,991	259
Lumber Products (24)	1,056	1,509	2,262	2,930	3,748	148
Furniture and Fixtures (25)	932	1,123	1,778	2,436	3,214	186
Stone, Clay and Glass Products (32)	766	1,134	2,042	2,941	4,015	254
Primary Metals (33)	1,057	1,590	2,730	3,804	5,095	220
Fabricated Metals (34)	1,131	1,764	3,307	4,811	6,593	273
Machinery (35 and 36) (including electric)	2,807	4,651	9,390	14,131	19,814	326
Transportation Equipment (37) (including motor vehicles)	1,700	2,242	3,887	5,513	7,455	233
Instruments (38)	192	395	881	1,423	2,076	426
Miscellaneous Manufacturing (39)	245	343	553	751	981	186
Manufacturing Nondurables	12,851	16,325	24,688	32,697	42,319	159
Food and Kindred Products (20)	1,871	2,388	3,278	4,148	5,156	116
Tobacco Products (21)	412	504	562	646	751	49
Textile Mill Products (22)	4,099	4,391	5,780	7,222	8,962	104
Apparel and Other Fabricated (23)	1,833	2,205	3,279	4,271	5,435	146
Paper and Allied Products (26)	1,117	1,602	2,528	3,337	4,326	170
Printing and Publishing (27)	821	1,139	2,033	2,846	3,805	234
Chemicals and Allied Products (28)	1,840	2,509	4,230	5,816	7,738	208
Petroleum Refining (29)	57	124	276	412	571	360
Rubber and Miscellaneous Plastics (30)	514	1,191	2,475	3,725	5,268	342
Leather and Leather Products (31)	221	231	247	275	307	33
Agricultural Production (01 & 02)	3,708	4,260	4,763	5,539	6,522	53
Mining	625	1,562	3,523	4,815	6,206	297
Coal Mining (11 & 12)	298	1,039	2,764	3,940	5,184	399
Crude Petroleum and Natural Gas (13)	67	152	290	310	336	121
Metal Mining (10)	25	17	27	30	34	100
Nonmetal Mining, excluding fuels (14)	205	319	442	535	652	104

Source: Calculated from U.S. Bureau of Economic Analysis 1980.

rubber (342 percent), fabricated metals (273 percent), and stone, clay and glass products (254 percent).

Based on their size, projected growth rates, and potential environmental impacts, four states--Florida, Georgia, North Carolina, and Tennessee--are predicted to have large concentrations of key industries.[1] These states will be characterized by concentrations of the core manufacturing sectors--pulp and paper, food processing, and stone, clay, and glass manufacturing. Industries which could threaten water resources are projected to have rapid growth rates; for example, textiles and primary metals could threaten water quality and pulp and paper is a large water consumer.

1.3 WATER RESOURCE CONCERNS

1.3.1 General Water Resource Problems

Of the potential environmental concerns associated with growth in the Sunbelt, water resource problems have been identified as one of the most significant (Science and Public Policy 1983). This can be attributed to three factors: (1) the potential for water quality degradation from industrial and population growth; (2) the possibility for water shortages to restrict growth; and (3) concerns about the capacity of various levels of government to manage emerging conflicts over the use and protection of water resources.

While water availability for growth has long been a problem throughout much of the Southwest, it typically is not considered to be a major concern in much of the Southeast. This conventional wisdom is reflected in Figure 1-2, which shows broad areas where water availability problems already exist or are projected to occur by the year 2000 (U.S. Water Resources Council 1978).[2] However, such characterizations frequently do not consider the relationship between water availability and water quality. As indicated in Figure 1-3, many parts of the Southeast experience water quality problems from point and nonpoint pollution. Areas experiencing multiple

---

[1] See Chapter 4 of the Environmental Status Report (Science and Public Policy 1983).

[2] Several site-specific water supply problems also exist throughout the Sunbelt but are not shown in this figure. The use of this figure and Figure 1-3 is intended to only to provide a very general characterization of the regional water picture. The methodology used by the study, which combined information from national and state data sources, is not appropriate for drawing conclusions about the exact location or severity of problems. See chapters 13 and 14 of Science and Public Policy Program (1983).

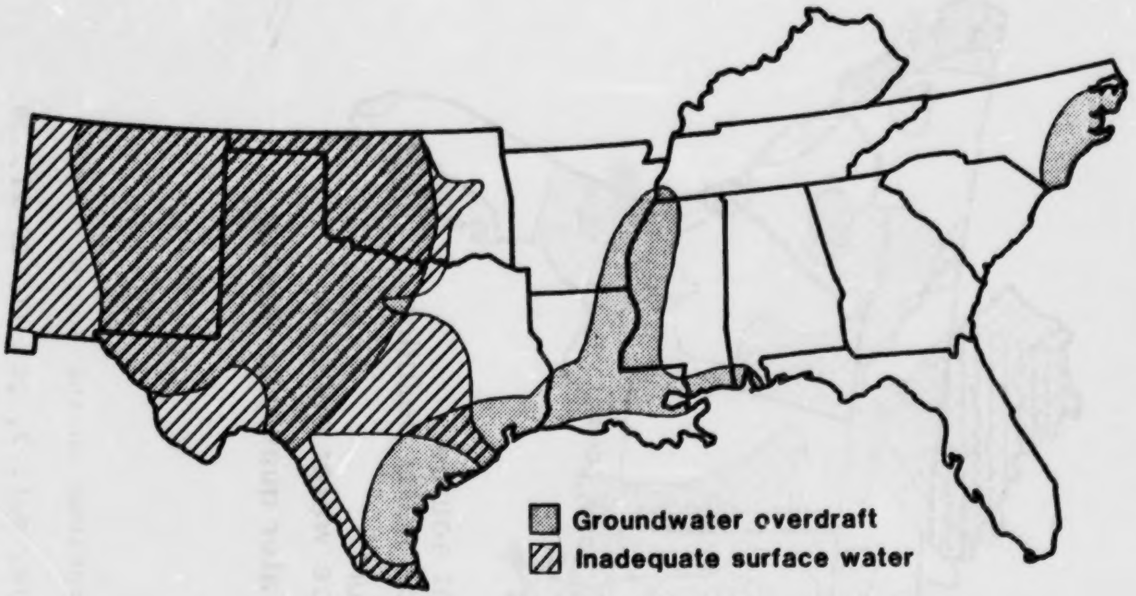


Figure 1-2: Current region-wide problems: water availability.

Source: Adapted from U.S. Water Resources Council 1978, pt. 5.2, 3-14.

water quality problems include much of the Gulf and South Atlantic coasts; most of Kentucky; large portions of northern Georgia and the eastern Carolinas; the lower Mississippi Region, and along the Tennessee-Tombigbee Waterway. This information suggests that water availability may well be a problem in the Southeast since water quality degradation could limit the future uses of water, especially for domestic purposes.

There are many sources of these pollution problems.[1] Most surface water point sources of pollution are municipal or industrial. Coliform bacteria from municipal waste or feedlot drainage and nutrients from municipal and industrial discharges constitute the majority of the point source problems. Industrial chemicals, heavy metals (mercury, zinc, copper, cadmium, lead, etc.), and heat from manufacturing and power generation are the other identified point sources of pollution. Most nonpoint sources of pollution are

---

[1] Refer to Chapter 14, of the Environmental Status Report (Science & Public Policy Program 1983) for an elaboration of these concerns.

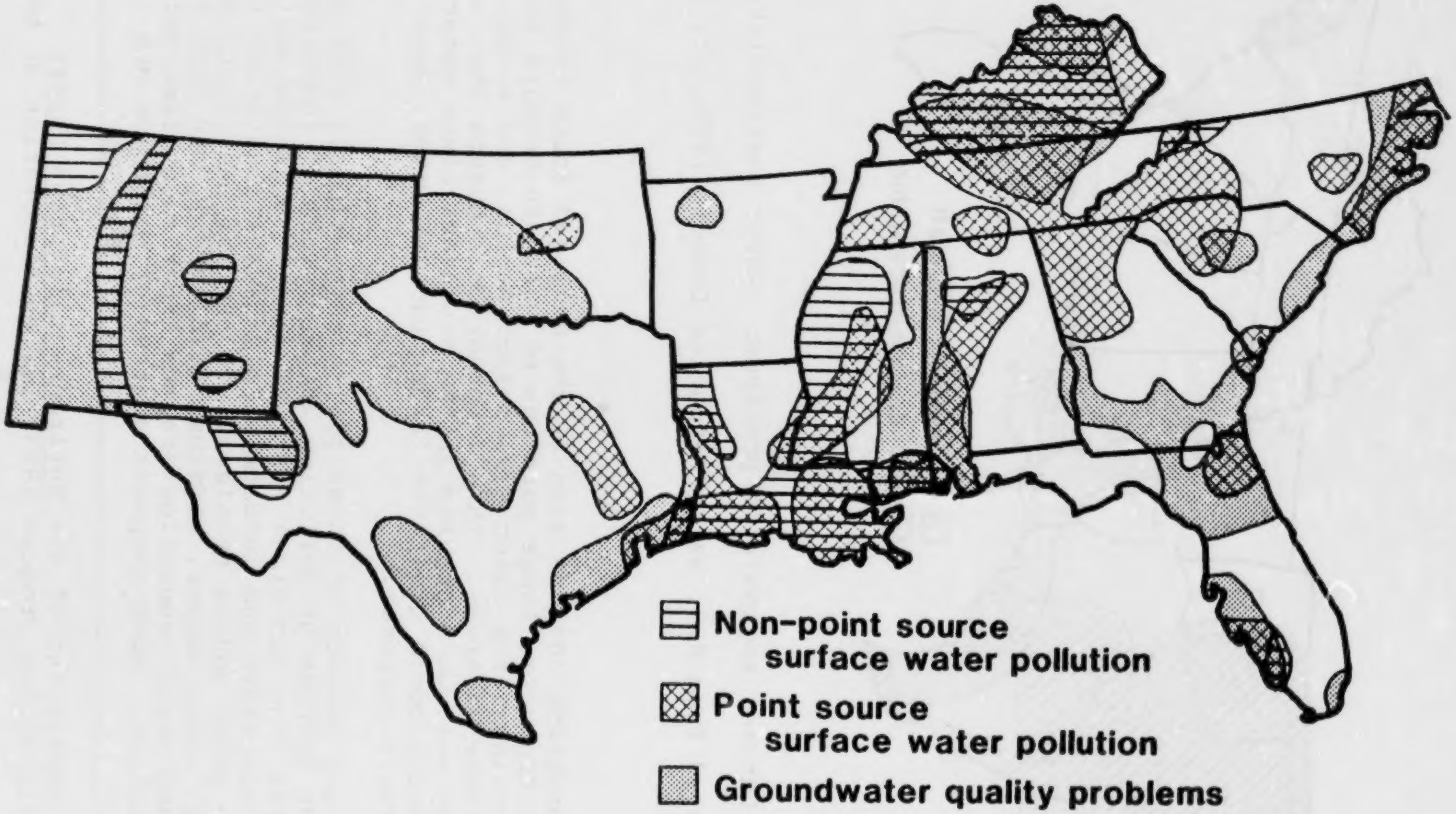

▤ Non-point source surface water pollution
▨ Point source surface water pollution
▒ Groundwater quality problems

Figure 1-3: Significant water quality problems in the South.

Source: U.S. Water Resources Council 1978, Vol. 2, pt. II, 20-21, 30.

irrigation runoff with high concentrations of dissolved solids, pesticides and other agricultural chemicals, urban runoff and leakage from fuel storage tanks. Mine drainage is a problem mainly in Kentucky, Tennessee, and northern Alabama.

Ground water pollution results from both natural and man-made causes. High levels of minerals or other dissolved solids occur in several parts of the study area including the Mississippi-Alabama border and west Florida. Saltwater intrusion occurs along many coastal areas. Specific sources of ground water pollution include municipal and industrial wastes, landfill leachate, septic tanks, leaching of fertilizers from agriculutural activities, wastes from well drilling, deep well injection of industrial waste liquids, and saltwater intrusion.

In addition, increased competition for water will occur in areas already experiencing multiple water quality problems. This includes growth of the chemical industry in the South Atlantic-Gulf region, primary metals in Kentucky and Tennessee, paper products in the South Atlantic-Gulf, and petroleum refining in the Lower Mississippi region. Increased agricultural production for food export and biomass for energy development is expected to occur in many parts of the Southeast, and rapid population increases are projected in Florida and along most of the Gulf coast.

1.3.2 Rationale For A Ground Water Study

Several components of the water resource problem deserve further attention. These include surface water management, ground water management, municipal water supplies, industrial water needs and impacts, agricultural water use, and others. This report addresses water resource concerns in the Southeast, with particular emphasis on ground water. There are five justifications for the focus on ground water:

- An Emerging Issue: The overall purpose of the Sunbelt project is to anticipate future concerns to the region. In most of the southeastern states, ground water has not received much public attention, but is likely to be an important concern in the 1980's and over the next several decades;

- Significance to Growth: As discussed above, the Southeast is undergoing rapid growth--in population, several major industries, and agriculture. Much of this growth could be affected by ground water resources, particularly given surface water quality problems and the increasing demands for surface water;

- Pervasiveness: Ground water problems are likely to be pervasive across the Southeast: Florida already experiences many problems, and issues are emerging along the South Atlantic coast, the Atlanta area and in southwest Georgia, the North Carolina and Virginia border; the Fall Line area of North and South Carolina; Lexington, Kentucky, and Chattanooga, Tennessee;

- Institutional Capacity: The policy system for ground water has lagged behind that for surface water. With some notable exceptions, state governments have not taken an active role in managing ground water resources; there are several uncertainties concerning federal-state relationships in ground water quality protection; and there are virtually no mechanisms to deal with interstate problems;

- Policy Responses: Relatively little attention has been paid to the evaluation of options for managing ground water, including assessments of the transferability of options tried in other states to the Southeast.

1.4 PURPOSES, SCOPE, AND AUDIENCE

The general purpose of this study is to anticipate water resource concerns which could constrain development or adversely affect the environmental quality of the region, and to suggest policy options for dealing with the most significant of these concerns. Specific purposes include:

- Providing a basis for anticipating long-term water trends in the Southeast, based on key driving forces, geographical areas subject to particular stress, and social and institutional factors;

- Identifying and establishing general priorities of ground water problems;

- Identifying options to improve ground water management capacity at the federal, state, and local levels, including:

  - identification of constraints to problem-solving;
  - identification and comparision of policy options, particularly those used in other states; and

- Suggesting needed improvements in water resource planning, including data and research needs, adequacy of water planning institutions, and key problems for future study.

Water resource issues will be addressed for the eight southeastern states from the present through the year 2000. Although the study will anticipate changes during this time period, it is not intended to be predictive of when specific problems will occur. Rather, the study will identify problems likely to occur during the next 20 years and discuss options for avoiding or mitigating these problems.

The general audiences for the study are water resource decisionmakers at the federal, regional, state, and local levels who have responsibility for water policy and water planning (R&D) activities. Because emphasis will be placed on ground water resources, a primary audience also will be state governments, including legislators who may be considering revision to laws and regulations affecting ground water, executive level agencies which have administrative, management, or enforcement responsibilities, and regional organizations or agencies that have multistate responsibilities.

1.5 ORGANIZATION OF THE REPORT

The remainder of this report describes the nature of water resource concerns in the Southeast and assesses specific ground water problems. Chapter 2, "Water Resource Concerns in the Southeast," provides a broad overview of water availability and quality, including a description of surface and ground water resources, current and predicted water use patterns, and a discussion of four water resource problems. These are point source pollution, nonpoint source pollution, water availability, and water management. Chapter 3, "Case Studies in the Southeast," describes ground water resource concerns in four areas of the Southeast. This is intended to provide a detailed picture of the relationship of ground water resources and pressures for growth. Each study area is a county or multi-county area.

Chapters 4 and 5 describe the most significant ground water problems likely to face the Southeast. Chapter 4, "Ground Water Quality Problems and Issues," discusses five categories of problems: waste disposal and underground injection, nonpoint pollution and land use practices, institutional and management issues, data and monitoring problems, and drinking water quality. Chapter 5, "Ground Water Availability Problems and Issues," describes use patterns, three physical problems (degradation related to depletion, lowered water tables, and subsidence), and several legal and institutional barriers to ground water management.

Chapters 6 through 9 provide an inventory of policy options for dealing with ground water problems. Chapter 6 discusses options which are specifically intended to address ground water quality problems. Categories of options in this chapter include sewage disposal management, agricultural practices management, urban runoff control, controlling mining and energy extraction practices, point source control, ground water quality standards, and aquifer rehabilitation. Chapter 7 identifies options to provide an adequate water supply, including legal and institutional changes, market options, augmentation, and conservation. Chapter 8 discusses land use management options, including comprehensive land use planning, several specific land use controls, and siting controls. Chapter 9 addresses state and local institutional development. Five specific options for improving institutional capacity are discussed; integrating the administration of ground water quality and availability, conjunctive use, emergency response capacity, critical use areas, and cooperative supply systems. In addition, three more general regulatory models used in Arizona, Nebraska, and Florida are characterized.

REFERENCES

Science and Public Policy Program. 1983. Southern Regional Environmental Assessment: Environmental Status Report. Environmental Protection Agency, Washington, DC: Office of Research and Development.

U.S. Bureau of the Census. 1980. Statistical Abstract of the U.S.: 1980. Washington, DC: Government Printing Office.

U.S. Department of Commerce. Bureau of Economic Analysis. 1980. Regional Economic Projections. Washington, DC: Bureau of Economic Analysis.

U.S. Water Resources Council (WRC). 1978. The Nation's Water Resources 1975-2000. Vol. 1, Summary. Second National Water Assessment. Washington, DC: Government Printing Office.

CHAPTER 2

WATER RESOURCE CONCERNS IN THE SOUTHEAST

2.1 INTRODUCTION

Water resources are a key ingredient to a healthy economy and environment. Water quality and availability must be managed to meet needs for human consumption and other domestic purposes, to supply industry and agriculture, to maintain aquatic ecosystems (which may be economically important), to provide recreational opportunities, and to maintain aesthetic qualities. Water supply has long been recognized as a problem in many parts of the U.S., especially in the Southwest which suffers from limited surface and ground water. Water is becoming a more serious concern in the Southeast, especially where water quality degradation has limited some uses. As economic and population growth continue, water quality and availability issues will increase. Key driving forces include expanded water needs for electricity generation, chemicals production, pulp and paper production, petroleum processing, agriculture, and population growth. The use of water for recreational purposes is also important to the attractiveness of the South (Science and Public Policy 1983, Ch. 2).

The purpose of this chapter is to provide a broad overview of water resource conditions, trends, and issues for the Southeast as a context for the more detailed analysis of ground water in the remainder of the report. Four criteria have guided the organization and content of this chapter: the need to consider the relationship between water availability and water quality; the need to integrate surface and ground water concerns; the importance of social, institutional, and political factors in dealing with water resource problems; and the need to anticipate future water resource concerns. Both surface and ground water are addressed in this chapter, but emphasis is given to surface water since the remainder of the report addresses ground water.

The following section (2.2) briefly describes the surface and ground water resources of the eight states. Current and projected water use patterns are discussed in Section 2.3. Then, four categories of water resource problems and issues are discussed: (1) point source pollution (2.4.1); (2) nonpoint source pollution (2.4.2); (3) water availability (2.4.3); and (4) water management (2.4.4). Each section presents information on the current status of the problem/issue and discusses future trends and policy issues. The final section (2.5) summarizes the key findings.

2.2 WATER RESOURCES

2.2.1 Surface Water Resources

The Southeast has many drainage basins that provide water for domestic and industrial uses, navigation, recreation, and other purposes. Some of the larger rivers (indicated in Figure 2-1), together with lakes and wetlands, make the region among the most water-rich in the nation. Florida, for example, with more than 4,400 square miles of inland area covered by water is second in the nation only to Minnesota, with 4,800 square miles (Geraghty et al. 1973). North Carolina ranks fourth, with 3,706 square miles of water-covered inland area.

The patterns of water flow depend primarily on precipitation, evaporation, and types of soil. Precipitation is highest (70 to 80 inches) in the Appalachian Mountain regions of Georgia, North Carolina, South Carolina, and Tennessee (Geraghty et al. 1973). Most of the region receives 50 to 60 inches of rainfall. In most states, the maximum precipitation occurs in early spring, with low rainfall in the fall. Typical of this case is Atlanta, shown in Figure 2-2. Another pattern exists in most of Florida, where the summer has abundant rainfall and the winter experiences very low rainfall. Typical of this pattern is Miami (see Figure 2-2), which averages only about 1.5 inches in December. However, in exceptional years, low rainfall can result in dry periods during any month. The Miami region, for example, has experienced less than a tenth of an inch of rain during some months (U.S. National Oceanic and Atmospheric Administration 1980a).

Longer term droughts have also occurred, contributing to the use of ground water resources by farmers, municipalities, and industries. For example, precipitation in the Atlanta area, which averages about 49 inches per year, was as low as 35, 32, and 36 inches in 1941, 1954, and 1955. Miami's average rainfall of 59 inches has been punctuated frequently by droughts of less than 40 inches.

Peak stream flow is tied to periods of maximum precipitation. Most of the region experiences seasonal peak flows during March or February, except in Florida, where peak flows typically occur in August through October. Low flows occur primarily during October, again except for Florida, where low flows usually occur during spring (Geraghty et al. 1973).

As show in Figure 2-1 there are four water resource regions in the Southeast (U.S. Water Resources Council 1978a): the Lower Mississippi Region, the Tennessee Region, the Ohio Region, and the South Atlantic-Gulf Region. The acreage included and the mean annual flow of these regions are shown in Table 2-1. As measured by total mean flow, each of these four regions are relatively water rich. The total mean flow of 518 bgd represents aproximately 25 percent of the nation's freshwater stream flow.

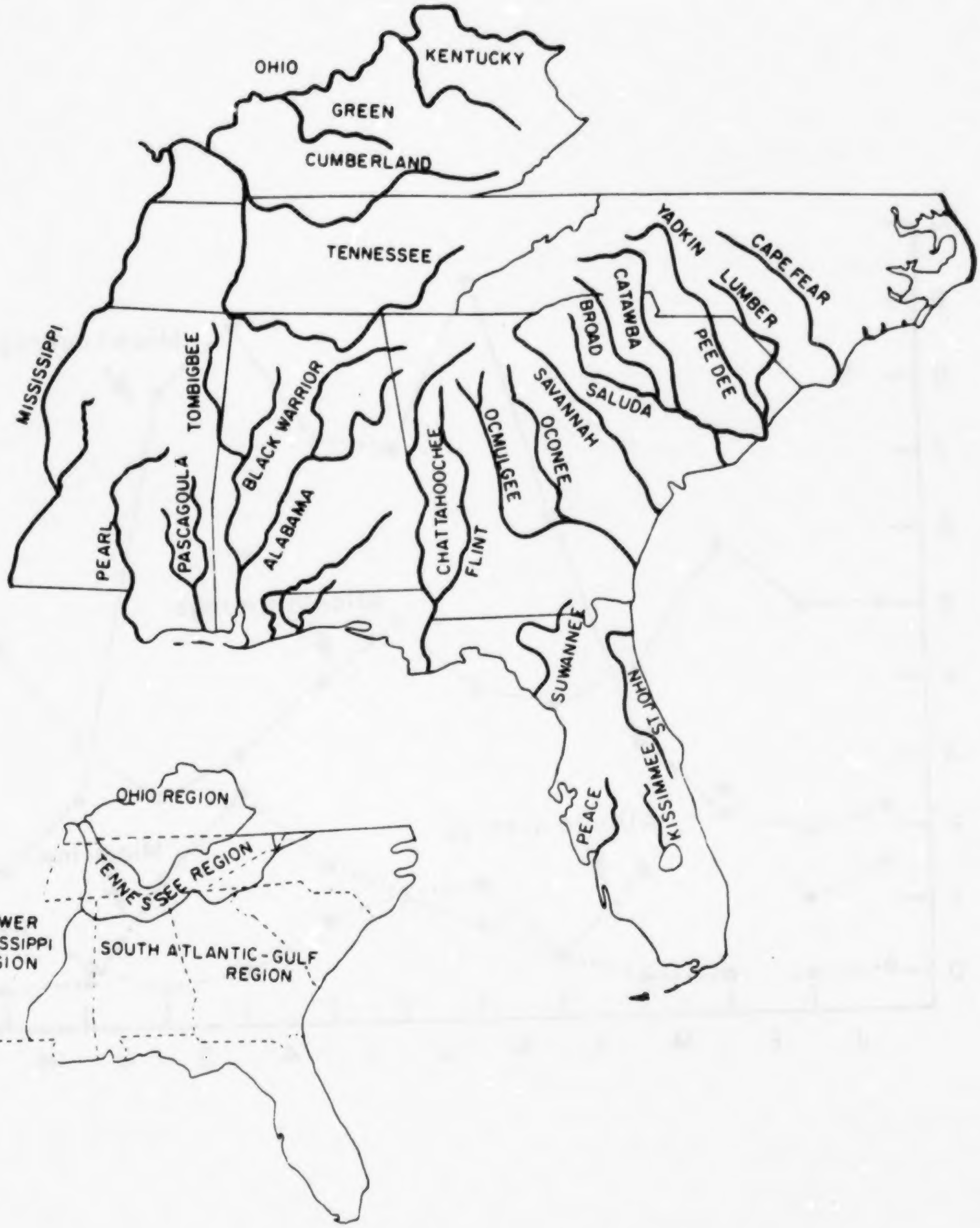


Figure 2-1: Major rivers of the Southeast and River Basin Regions.

Source: Modified from U.S. EPA 1978.

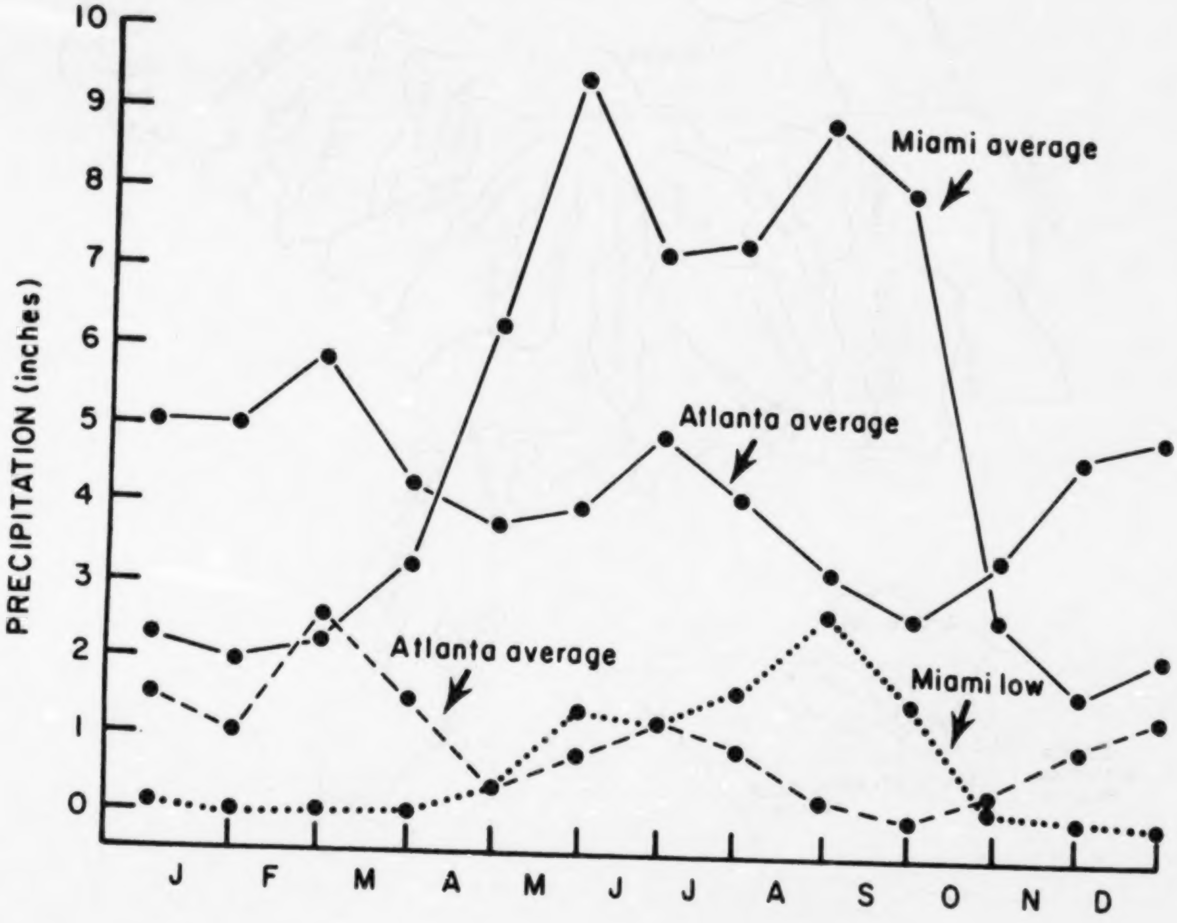


Figure 2-2: Average monthly and record low monthly precipitation from 1941 to 1980 at Atlanta and Miami.

Source: Data from U.S. National Oceanic and Atmospheric Administration 1980a, b.

TABLE 2-1: WATER RESOURCE REGIONS IN THE SOUTHEAST[a]

Region	Area (millions of acres)	Total Mean Annual Flow (billions of gpd)
South Atlantic Gulf Coast	174	228
Lower Mississippi	67	71[b]
Tennessee	27	41
Ohio	102	178
Total	370	518

Source: Adapted from data in U.S. Water Resources Council 1978a, 15; U.S. Water Resources Council 1978d, 13.

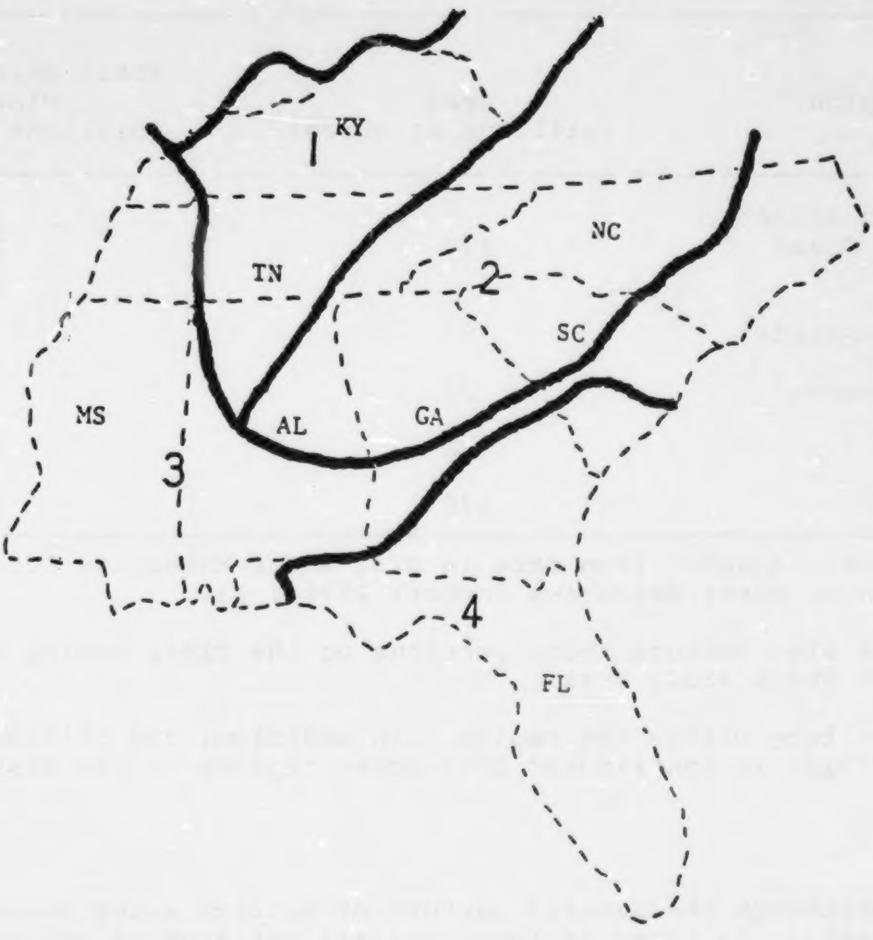
[a] Data also include those portions of the river basins outside the eight state study area.

[b] Flow from within the region. In addition, 362 billion gallons per day (bgd) is contributed from other regions of the Mississippi.

Although the general pattern of surface water resources can be summarized in terms of these overall patterns of regional flows, the problems of water management are also manifested on a stream-by-stream basis. The case studies described in Chapter 3 provide more specific examples of water resource characteristics at four southeastern sites.

2.2.2 Ground Water Resources

Ground water is more difficult to characterize; for example, agreement does not exist regarding the number of unique ground water regions underlying the Southeast. Thomas (1951) originally devised ten different ground water regions for the U.S., including three for the Southeast. Heath (1982) has proposed that the ground water resources of the United States be grouped into fourteen different regions, with four of these regions encompassing the Southeast (Figure 2-3). The ground water resources of the Southeast using the four regions shown in Figure 2-5 are discussed briefly below.



1 - Nonglaciated Central Region
2 - Piedmont and Blue Ridge Region
3 - Atlantic and Gulf Coast Plains Region
4 - Southeast Coastal Plains Region

Figure 2-2: Ground water resources of the Southeast.

Source: Heath 1982.

A. Nonglaciated Central Region

The Nonglaciated Central Region encompasses most of Kentucky, the central portion of Tennessee, and the northwest corner of Alabama. This region generally is characterized by consolidated rock aquifers whose productivity is limited by moderate to low yield (Zuranski 1978). Aquifers in most of the region are dolomite, limestone, and sandstone with low to moderate productivities. The region also contains some of the least productive aquifers in the United States. Generally, ground water is adequate for domestic supply, but inadequate for irrigation and other heavy uses. Exceptions to the low productivity characteristic of the region are the limestone formations in northern Alabama and a strip running Kentucky and Tennessee. Wells topping the alluvium of the Ohio River between Kentucky and Indiana also can be relatively productive.

B. Piedmont and Blue Ridge Region

The Piedmont and Blue Ridge Region encompasses the northeastern corner of Alabama, the northern halves of Georgia and South Carolina, the eastern one-third of Tennessee, and approximately the western two-thirds of North Carolina. The productivities of aquifers in this region are usually low to moderate or erratic (United Nations 1976). The weathered and fractured rocks of the Piedmont are among the most reliable aquifers in the country for the small yields needed for domestic supplies and are tapped by hundreds of thousands of rural and suburban wells. Well yields generally are less than 50 gallons per minute (gpm) and, in areas such as the Alabama Piedmont, are less than 10 gpm. However, the ground water resources and yields of the area have, for the most part, been underrated (U.S. Water Resources Council 1978e). The Blue Ridge is an unproductive ground water area because storage and transmission are limited to the fractures and negolith. The Valley and Ridge province is erratic in terms of ground water production with some limestone and sandstone strata yielding moderate supplies consistently.

The variability of aquifer productivity results in high exploration costs, thereby strongly influencing the efficient and economical development of the ground water resources in the region. For example, in the carbonate aquifers it is possible to drill dry holes within a few hundred feet of wells capable of producing several thousand gallons per minute.

C. Atlantic and Gulf Coast Plains Region

The Atlantic and Gulf Coastal Plains Region follows an arch from Mississippi through the southern half of Alabama, narrowing to a strip through the middle of Georgia and then fanning out to include the coastal halves of South and North Carolina.

This region has been described as a huge seawards thickening wedge of generally unconsolidated sedimentary rocks (United Nations 1976). The coastal plains represent the rock waste of almost the eastern two-thirds of the country washed seaward and distributed along the shore by streams and sea currents. As the sediments accumulated and the ocean level declined, the shoreline moved seawards leaving behind the highly unconsolidated coastal plains. Large quantities of ground water are available in the unconsolidated and semiconsolidated aquifers; locally, wells can yield several hundred gpm from sand aquifers.

One or more productive limestone aquifers are found in large areas in the Southeast, beginning in the southern half of the South Carolina Coastal Plain and continuing around into south-central Alabama. Both sand and limestone aquifers are found in parts of the South Carolina and Georgia Coastal Plain.

D. Southeast Coastal Plain Region

The Southeast Coastal Plain Region is really an extension of the Atlantic and Gulf Coastal Plain and includes parts of Alabama and South Carolina, about the southeastern one-third of Georgia, and all but a small portion of Florida.

The Southeast Coastal Plain is distinguished from the Atlantic and Gulf Coastal Plain in two ways. First, a large portion of the region is underlaid by carbonate rock with sand and gravel aquifers overlying these deeper aquifers. Second, the productivity of the aquifers of this region, especially in Florida, is virtually unmatched throughout the United States (United Nations 1976). The Biscayne and Floridan aquifers are two highly productive and highly utilized aquifers in Floridan. There exists potential for additional development of these and other aquifers; however, consideration must be given to the potential problems of saltwater intrusion and land subsidence from such development.

2.3 WATER USE PATTERNS[1]

Estimates of surface and ground water use by water resource region for 1980 are shown in Table 2-2. Total fresh water withdrawals, including surface water and ground water, are highest in the Ohio and South Atlantic-Gulf regions. Consumption is highest

---

[1] A detailed discussion of ground water use patterns is provided in Section 5.2.1

TABLE 2-2: FRESH WATER USE IN WATER RESOURCE REGIONS OF THE SOUTHEAST, 1980[a] (billions of gpd)

Water Resource Region	1980 Fresh Water Withdrawals			1980 Consumption	Percent Consumed[b]
	Surface	Ground	Total		
South Atlantic-Gulf	27	6.6	33.6	5.1	15
Ohio	35	2.5	37.5	1.7	5
Tennessee	12	.3	12.3	.4	3
Lower Mississippi	14	6.7	20.7	7.1	34
Southeast Regions	88	16.1	104.1	14.3	14
U.S.	290	88.0	378.0	100.0	26

Source: U.S. Water Resources Council 1978b, 25.

[a] Does not include hydroelectric power generation.

[b] Ratio of consumption to total fresh water withdrawals.

in the Lower Mississippi and South Atlantic-Gulf regions-accounting for 85 percent of the total consumption of the four Southeast regions.

Tables 2-3 and 2-4 present fresh water withdrawals and consumption by major use categories for each of the southeastern states. Alabama (10.6 bgd), Tennessee (10.1 bgd), North Carolina (8.1 bgd), and Florida (7.4 bgd) withdraw the largest amounts of water. Mississippi, on the other hand, only withdraws about 2.9 bgd of fresh water. Florida (38 percent) and Georgia (17 percent) account for 55 percent of the region's water consumption, reflecting the importance of irrigated agriculture to their economies. Irrigated agriculture is also important in Mississippi and represents 70 percent of that state's water consumption.

The use of fresh water by utilities for the generation of electricity is by far the largest category of water withdrawals in the Southeast--37.2 bgd or 66 percent of the total withdrawals. In every state except Mississippi (39 percent) and Florida (25 percent), thermoelectric power generation accounts for at least 53 percent of the surface and ground water withdrawn. However, fresh water consumption for electricity generation is quite low, representing only 7 percent of total consumptive use. Large withdrawals

TABLE 2-3: FRESH WATER WITHDRAWALS IN THE SOUTHEAST, 1980[a]

State	Public Supply[b]	Rural Use[c]	Irri-gation	Self-Supplied Industrial		State Total
				Thermoelectric Power[d]	Other Industries[e]	
Alabama	620[f]	193	33	8,500	1,251	10,597
	(6%)[g]	(2)	(<1)	(80)	(12)	
Florida	1,400	310	3,000	1,870	780	7,360
	(19)	(4)	(41)	(25)	(11)	
Georgia	770	161	580	4,400	780	6,691
	(12)	(2)	(9)	(66)	(12)	
Kentucky	357	99	5	4,015	320	4,796
	(7)	(2)	(<1)	(84)	(7)	
Mississippi	292	49	970	1,117	457	2,885
	(10)	(2)	(34)	(39)	(16)	
North Carolina	570	176	132	4,300	2,890	8,068
	(7)	(2)	(2)	(53)	(36)	
South Carolina	348	87	54	5,200	457	6,146
	(6)	(1)	(<1)	(85)	(7)	
Tennessee	510	85	13	7,800	1,690	10,098
	(5)	(1)	(<1)	(77)	(17)	
Southeast	4,867	1,160	4,787	37,202	8,625	56,641
	(9)	(2)	(8)	(66)	(15)	

Source: Solley, Chase, and Mann 1983, 10, 14, 18, 23.

[a] Does not include hydroelectric power generation.

[b] Water withdrawn by public and private suppliers and delivered to a variety of uses for domestic, public, industrial, and commercial use.

[c] Includes self-supplied water used in suburban or farm areas for domestic and livestock needs.

[d] Includes water used to generate electric power using coal, oil, natural gas, geothermol, or nuclear energy.

[e] "Other" self-supplied water industries include, but are not limited to, steel, chemical and allied products, paper and allied products, mining, and petroleum refining.

[f] Millions of gallon per day.

[g] Some row percentages do not add to 100 percent due to rounding.

TABLE 2-4: FRESH WATER CONSUMPTION IN THE SOUTHEAST, 1980[a]

				Self-Supplied Industrial		
State	Public Supply[b]	Rural Use[c]	Irri-gation	Thermoelectric Power[d]	Other Industries[e]	State Total
Alabama	44[f] (8)[g]	188 (33)	33 (6)	29 (5)	270 (48)	564
Florida	330 (14)	101 (4)	1,500 (62)	32 (1)	470 (19)	2,433
Georgia	180 (17)	113 (11)	580 (55)	120 (11)	59 (6)	1,052
Kentucky	23 (8)	87 (30)	5 (2)	140 (49)	33 (11)	288
Mississippi	100 (14)	45 (6)	500 (70)	33 (5)	36 (5)	714
North Carolina	110 (15)	179 (24)	130 (17)	67 (9)	270 (36)	756
South Carolina	53 (19)	87 (32)	54 (20)	35 (13)	47 (17)	276
Tennessee	55 (20)	54 (20)	9 (3)	1 (<1)	150 (56)	269
Southeast	895 (14)	854 (13)	2,811 (44)	457 (7)	1,335 (21)	6,352

Source: Solley, Chase, and Mann 1983, 10, 14, 18, 23.

[a] Does not include hydroelectric power generation.

[b] Water withdrawn by public and private suppliers and delivered to a variety of uses for domestic, public, industrial, and commercial use.

[c] Includes self-supplied water used in suburban or farm areas for domestic and livestock needs.

[d] Includes water used to generate electric power using coal, oil, natural gas, geothermol, or nuclear energy.

[e] "Other" self-supplied water industries include, but are not limited to, steel, chemical and allied products, paper and allied products, mining, and petroleum refining.

[f] Millions of gallon per day.

[g] Some row percentages do not add to 100 percent due to rounding.

with small consumption are attributed to the prevailing use of once-through cooling processes. In the past, over 99 percent of the withdrawals have been returned to the receiving stream at elevated temperatures. This practice is no longer used because of the Federal Water Pollution Control Act of 1972, which restricts thermal discharges. The restriction, which is intended to protect water quality, will lead to increased water consumption for electricity generation.

Water use patterns in the Southeast will change in response to increased population, economic development, water pollution control regulations, and changing land use patterns. The U.S. Water Resources Council (1978b) has projected that fresh water consumption in the Southeast will double by the year 2000, from 6.3 bgd in 1980 to about 12 bgd (Table 2-5).

If such a large increase occurs, most of it will likely be attributable to manufacturing and steam electric demands. Steam electric uses are projected to increase by over 500 percent between 1980 and 2000, with large increases expected in every state except Florida and Mississippi.[1] Overall, electricity generation is expected to account for 23 percent of consumptive use by 2000 (Shepherd et al. 1980).

Manufacturing consumption is expected to increase by about 140 percent, largely in Florida, Alabama, Tennessee, and Georgia. Nationwide, withdrawals of water for manufacturing are projected to decline over the next two decades. However, in the Southeast, they are projected to increase. By the year 2000, the South Atlantic-Gulf region is projected to become the largest water using region in both withdrawals and consumption. In 1980, this region ranked third in fresh water withdrawals with only 5 percent of total manufacturing withdrawals (Solley, Chase, and Mann 1983, 24, 37). Two growth factors contribute to this projection: (1) the region is expected to continue to experience rapid population growth, and (2) the major projected growth industries have high consumption rates and produce wastewaters that are less recyclable than most other water intensive industries (U.S. Water Resources Council 1978d, 42-44).

---

[1] These large projected increases are due to a combination of increased electrical generation capacity and the increased use of wet cooling towers in place of once-through cooling. However, more recent experience energy projections show a much slower growth in electricity demand than was generally projected in the mid-1970's. For the four water resource regions covering the southeastern states, the projections were based on a 521 percent increase in total electricity generation between 1975 and 2000 (U.S. Water Resources Council 1978c, 34).

TABLE 2-5: PROJECTED WATER CONSUMPTION IN THE SOUTHEAST, 2000 (billions of gpd)

State	Agriculture	Steam Electric	Manufacturing	Domestic	Other	State Total
Alabama	.07	.51	.58	.07	.05	1.28
Florida	3.20	.17	.73	.48	.17	4.75
Georgia	.28	.40	.44	.19	.07	1.38
Kentucky	.09	.35	.20	.06	.09	.79
Mississippi	.35	.11	.22	.09	.04	.81
North Carolina	.15	.44	.29	.24	.04	1.16
South Carolina	.03	.35	.27	.09	.03	.77
Tennessee	.06	.47	.45	.08	.05	1.11
Southeast	4.23	2.80	3.18	1.30	.54	12.05

Source: Shepherd et al. 1980, Table C.2.

Specific information on manufacturing water use and growth trends is presented in Table 2-6 for four key industries: chemical and allied products, primary metals, paper and allied products, and petroleum and coal products. These four industries are already among the most important industries in the Southeast and are projected to continue to grow through the year 2010. As indicated, fresh water withdrawals are expected to show a substantial reduction through the year 2000 for all four industrial groups. These reductions can be attributed to large-scale use of saline water and intensive recycling of fresh water, in part to comply with the Clean Water Act of 1977. In contrast to reduction in withdrawals, consumption is projected to increase. This projection can be attributed to the increased use of evaporative holding ponds to meet the goals of the Clean Water Act and increased production levels. For example, consumption in paper manufacturing is expected to increase over 450 percent by 2000 in the South Atlantic-Gulf region.

TABLE 2-6: WATER USE BY MAJOR INDUSTRIES BY WATER RESOURCE REGIONS, 1975 AND 2000 (millions of gpd)

Industry/Region	Withdrawals 1975	Withdrawals 2000	Withdrawals Percent Change	Consumption 1975	Consumption 2000	Consumption Percent Change	Consumption Percent of National Consumption 2000[a]
Chemicals							
South Atlantic-Gulf	870	748	-14	165	589	+256	14
Ohio	3,261	593	-82	168	464	+176	11
Tennessee	1,520	336	-78	81	262	+223	6
Lower Mississippi	2,251	635	-72	141	504	+257	12
Primary Metals							
South Atlantic-Gulf	270	145	-46	51	115	+125	4
Ohio	6,346	1,050	-83	467	834	+ 79	31
Tennessee	77	33	-57	12	25	+108	1
Lower Mississippi	535	101	-81	29	46	+ 59	2
Paper							
South Atlantic-Gulf	2,111	1,875	-11	262	1,492	+469	36
Ohio	224	133	-41	23	101	+ 77	2
Tennessee	381	246	-35	41	196	+378	5
Lower Mississippi	517	381	-26	46	304	+560	7
Petroleum Refining							
South Atlantic-Gulf	28	25	-11	12	20	+ 67	2
Ohio	114	48	-58	23	38	+ 65	4
Tennessee	0	0	0	0	0	0	0
Lower Mississippi	441	150	-66	66	119	+ 80	12

Source: Data compiled from U.S. Water Resources Council 1978d, 46-51.

[a] This column reflects the amount of water consumed by each industry for each particular region as a percentage of the water consumed by that industry nationwide.

2.4 WATER RESOURCE PROBLEMS AND ISSUES

Several water quality and availability concerns are important to the future development of the Sunbelt. Four categories of water resource problems will be discussed in the remainder of this chapter: point source pollution, nonpoint source pollution, water availability, and water management. These problem categories were determined to be among the most important water resource concerns based on three criteria: (1) they affect multiple areas throughout the Southeast, (2) they have important economic or environmental implications, and (3) they will have long-term consequences for growth in the region.

2.4.1 Point Source Pollution

Point source pollution is associated with municipal sewage treatment facilities and heavy industries such as steel, chemicals, pulp and paper, and food processing. Table 2-7 shows data on river basins affected by point source discharges, either industrial or municipal.[1] Although these data are considered to present a good overview of the extent of pollution from these sources (U.S. CEQ 1979), they have two general limitations. First, they can overstate the extent of some pollution since only a part of a basin may be affected. Second, some problems may not be reflected in these data; for example, monitoring data may not be adequate to identify some problems related to toxic pollutants.

Based on these data, surface water pollution from point sources is widespread across the U.S., including the Southeast. In this region, 74 percent of the basins are affected by industrial discharges, while 91 percent are affected by municipal effluents. The most widespread pollution problems in the Southeast are bacteria, oxygen depletion, and nutrients. Heavy metal pollution affects 36 percent of the basins in the Southeast.

Figure 2-4 provides a different perspective on surface water quality problems caused by point source discharges. The shaded areas indicate "significant" water quality problems as identified by federal and state/regional study teams as part of the Second National Water Assessment (U.S. Water Resources Council 1978b, pt. 2, 20). Although the unshaded areas may have problems, they were not considered major by the study teams. The majority of significant problems are nutrients from municipal and industrial discharges and coliform bacteria from municipal waste or feedlot

---

[1] These figures are based on field data collated by the states in 1975 and 1976. Basins are classified as "affected" if the problems identified were not considered minor or insignificant, but this does not necessarily mean that water quality standards were violated.

TABLE 2-7: WATER POLLUTION IMPACTS FROM POINT SOURCES, 1977 (percent of basins affected)[a]

Pollutant	Southeast[b]	U.S. Total
Type of Point Source		
Industrial	74	72
Municipal	91	89
Pollution Type		
Thermal	11	15
Bacteria	77	78
Oxygen depletion	89	79
Nutrients	70	69
Suspended solids	26	35
Dissolved solids	9	17
pH	17	14
Oil and grease	6	16
Heavy metals	36	38
Nonmetal toxics	28	28

Source: U.S. EPA 1978, 11.

[a] Basins where some (or all) stream segments have a problem that is not minor or insignificant, according to state officials. The total number of basins is: Southeast Region, 47; Southcentral Region, 30; U.S. 246.

[b] Note that the regional drainage basin groupings used here do not conform precisely to the boundaries of the eight states. The Southeast Region includes the Southeast and Tennessee River basins, while the Southcentral Region includes the lower Mississippi River and western Gulf of Mexico basins.

drainage. Two areas are indicated as having significant problems due to toxic materials such as heavy metals and polychlorinated biphenyls (PCBs).

As the Sunbelt continues to industrialize and grow in population, the potential for pollution from point sources will also increase. However, the actual level of pollution and its effects will depend on the degree of wastewater treatment applied, the particular industrial processes involved, and the siting of the discharge points. Table 2-8 shows projections for key driving forces and indicates pollutants of primary concern for each category. The industries listed in Table 2-8 are important because of a large projected growth (ranging from 41 to 352 percent) and significant

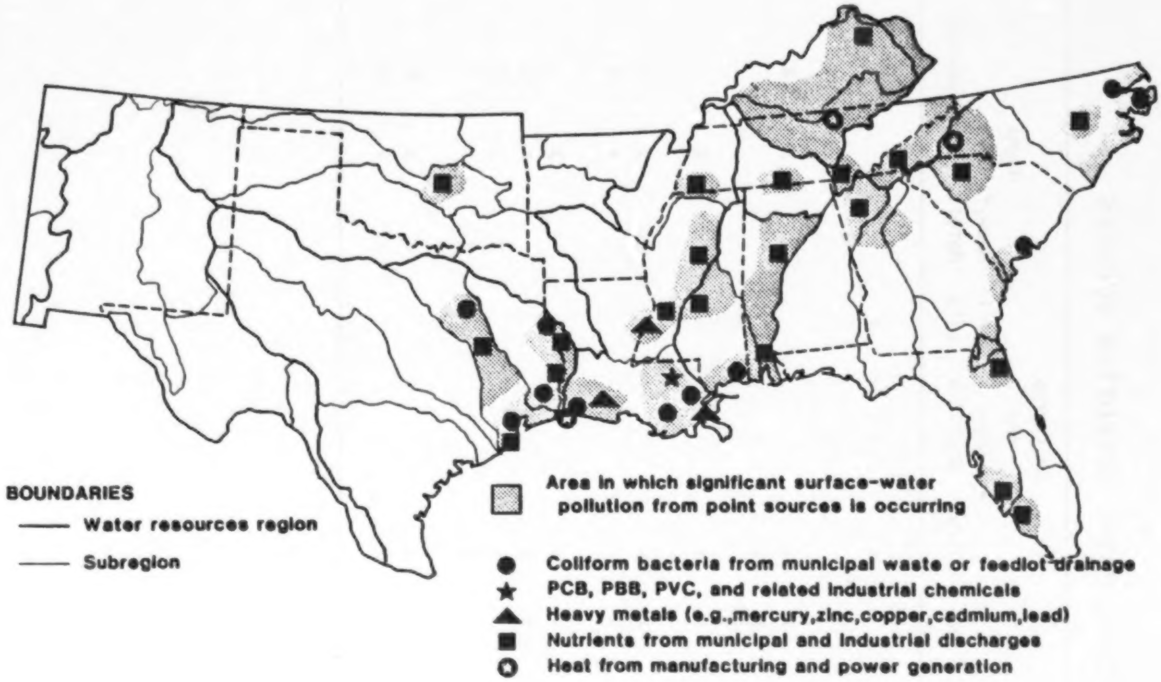

BOUNDARIES
Water resources region
Subregion
Area in which significant surface-water pollution from point sources is occurring
Coliform bacteria from municipal waste or feedlot drainage
PCB, PBB, PVC, and related industrial chemicals
Heavy metals (e.g.,mercury,zinc,copper,cadmium,lead)
Nutrients from municipal and industrial discharges
Heat from manufacturing and power generation

Figure 2-4: Surface water pollution problems from point sources. (municipal and industrial waste)

Source: U.S. Water Resources Council 1978b, pt. 2, 20.

wastewater treatement requirements. However, in many cases only certain subclasses of these industries are a potential water quality concern; thus, growth in a broad category does not necessarily imply a proportional growth in water pollution potential. For example, the "Paper and Allied Products" category includes many economic activities, but the only one of major water quality concern is pulp and paper production.

Table 2-8 also indicates that population growth is projected to increase 30 percent in the region by 2010. If this occurs, the potential for water quality degradation from domestic wastewater, both from centralized municipal sewage treatment plants and from individual systems, such as septic tanks, will also increase. In addition, activities associated with population growth, such as urban development and highway construction, can increase nonpoint source runoff problems (see Section 2.4.2).

TABLE 2-8: SIGNIFICANT POTENTIAL POINT POLLUTION SOURCES

Driving Forces	Earnings in the Southeast (millions of 1972 dollars) 1978	2010	% change	BOD	Solids[a]	Coliforms and Other Bacteria	Nutri- ents	Heavy[b] Metals	High/ Low pH	Organics[c]	Pest- icides
Population[d]	38.9 (1980)	50.6	+30	X	X	X	X				
Industry (SIC Code)											
Textile Mills (22)	4,391	8,962	+104	X	X				X	X	
Food Processing (20)	2,388	5,156	+116	X	X	X					
Paper and Allied Products (26)[e]	1,602	4,326	+170	X	X				X		
Chemicals and Allied Products (28)	2,509	7,738	+208	X	X			X	X	X	X
Petroleum Refining (29)	124	571	+360	X	X				X	X	
Rubber, and Misc. Plastics (30)	1,191	5,268	+342	X	X				X		
Leather and Products (31)	231	307	+33	X	X				X	X	
Primary Metals (33)	1,509	5,095	+220		X			X	X	X	
Fabricated Metals (34)	1,764	6,593	+273		X			X		X	
Transportation Equipment (37)	2,242	7,455	+223		X			X	X	X	
Machinery (35 and 36)	4,651	19,814	+326		X			X	X	X	

Sources: Nemerow 1978; U.S. Bureau of Econmic Analysis 1980a, b.

[a] Includes suspended and dissolved solids and increased salinity.

[b] Includes mercury, zinc, copper, cadmium, and lead, etc.

[c] Includes hydrocarbons and toxic organic chemicals.

[d] Population is shown in millions of persons.

[e] Excludes pulp and paper earnings.

Most of the major pollution control efforts under the impetus of the Clean Water Act have focused on point sources--initially on "conventional" pollutants (BOD, suspended solids, etc.) and more recently on toxic substances. The basic regulatory structure for requiring stringent controls is in place under the National Pollution Discharge Elimination System (NPDES) program. However, there are still many difficult technical and economic problems associated with implementing these pollution control programs; for example, of the 5,623 municipal sewage treatment projects begun since 1972, only 1,552 were in operation as of December 1979. The Council on Environmental Quality's analysis of national water quality trends between 1975 and 1979 for six water quality indicators showed little or no change.[1] That is, while many heavily polluted basins have substantially improved and others have continued to deteriorate, a high percentage of basins showed no significant change. This underscores the fact that it will be several more years before the full effect of water pollution regulatory efforts is evident (U.S. Council on Environmental Quality 1980, 100).

Long-term water pollution trends from point sources in the Sunbelt depend on a complex set of factors. Population and industrial growth will lead to greater amounts of domestic sewage and industrial wastewater which will require treatment and disposal. In contrast, if current regulations are implemented and enforced, the quantities of pollution discharged per unit of population and per unit of industrial production will be reduced. However, the effectiveness of controls will vary by pollutant type and source, and changes in water use patterns and hydrology can affect the quantities of water in receiving streams, thus affecting pollution concentration levels. An important research need in this regard is to assess long-term water pollution trends on a river basin or state basis.

In its Environmental Outlook 1980, the EPA analyzed water pollution trends from a variety of sources, including municipal and industrial point sources on a broad geographical basis (U.S. EPA. Office of Research and Development 1980, Ch. 6).[2] This study, based largely on the Strategic Environmental Assessment System (SEAS), analyzed several different pollutants both regionally and nationally. For each pollutant, three categories were considered: (1) gross generation--the amount of a pollutant which exists in wastewaters of a plant before being subject to treatment; (2) net discharges--the amount of a pollutant that would be discharged in waste streams even after full treatment to meet the standards required by law; and (3) intermediate discharges--calculated as the level of a pollutant discharged if removal efficiencies were to remain at their 1975 level. The Southeast was projected to experience large economic and population growth resulting in substantial increases in gross generation of pollutants. However, if stringent levels of pollution control are assumed (i.e., if all applicable laws and regulations are met), net discharges to waterways from these point sources were projected to decline for most pollutants.[1] Exceptions were dissolved solids, which are not covered by effluent guidelines, and nitrogen, largely due to releases from municipal sewage facilities and the organic chemicals industry. If only intermediate discharge levels were met, pollutant loadings were projected to increase generally by at least a factor of 2. In short, this analysis showed the importance of enforcing existing or proposed effluent guidelines if point source water pollution is to be improved or maintained in the Sunbelt.

---

[1] Data were from the U.S. Geological Survey's National Stream Quality Accounting Network.

[2] Although there are many uncertainties and possible sources of error in such projections, the analysis is useful in helping to understand the interrelationships between driving forces and water pollution and the general trends shown are reasonable given the underlying assumptions (U.S. EPA. Office of Research and Development 1980, Ch. 6).

In summary, many sites throughout the Southeast are currently experiencing serious point source water pollution problems. In contrast to nonpoint sources (discussed below), the basic regulatory structure is in place through the NPDES program to control pollution from point sources, although serious questions about compliance remain. Past efforts under this program have resulted in dramatic improvements in discharge levels and receiving water quality in many specific areas. If current standards are met, improvements can be expected to continue. However, even if these controls were to be stringently enforced, continued degradation can be anticipated in some areas due to expanding population and industry. Of course, the water quality changes and resulting impacts will be highly site-specific. Finally, much more work is required in the area of toxics. Water quality management agencies have a good understanding of conventional pollutants from point sources, but not of toxics. Water quality standards and monitoring networks do not address many toxics in most states, and the EPA only recently published ambient criteria for 65 priority toxic pollutants (U.S. EPA, Office of Water Programs Operations 1981, 7).

---

[1] The Environmental Outlook 1980 report analyzed trends for selected toxic chemicals, but generally on a national basis rather than on a detailed regional basis. Also, although the importance of toxic pollutants is recognized, there is a considerable lack of systematic data on industrial discharges, especially in the case of toxic organic chemicals. Consequently, the SEAS toxic pollution estimates were fragmentary and cover only a small fraction of the 65 classes of priority toxic pollutants recognized by EPA.

2.4.2 Nonpoint Source Pollution

Surface and ground waters also are significantly affected by nonpoint sources of pollution, both natural and manmade. In contrast to point sources, nonpoint sources of water pollution are not as well understood or documented, they are generally more difficult to control, and very little improvement was achieved during the past decade in reducing their impacts.

No specific authority has been given to the EPA to regulate nonpoint source pollution--the Clean Water Act left the development and implementation of specific control regulations up to state and local governments. However, the EPA has been attempting to address nonpoint pollution primarily through the Water Quality Management Program created by Section 208 of the Clean Water Act. Section 208 established procedures under which state or regional agencies are required to prepare water quality management plans which include both point and nonpoint sources. The EPA must approve the plans prepared by the designated planning agency, but the plans are not binding (Dolgin and Guilbert 1974, 767). Several other federal and state programs also affect nonpoint sources. Section 208(j) of the Clean Water Act authorizes the Department of Agriculture to provide grants for controlling agricultural pollution problems in areas or states with approved 208 plans. The Surface Mining Control and Reclamation Act of 1977 has provisions for controlling nonpoint source pollution from mining. In cooperation with the Soil Conservation Service, the states have several soil erosion control programs. Part of the purpose of the 208 planning process was to assure coordination among these various programs (U.S. EPA 1978, 26). However, EPA 208 grants have recently been eliminated or are being phased out.[1] The extent to which these programs might be carried on by the states is unclear at the present time. This policy shift could represent a major set-back for attempts to control nonpoint sources, unless funding through Section 205(j) replaces the 208 program.

Based on the 1977 EPA National Water Quality Inventory Report to Congress, states reported that 87 percent of the basins across the country are affected by nonpoint source pollution (U.S. EPA. 1978, 15). Table 2-9 indicates the percent of basins affected for the Southeast and nationally, both by the type of nonpoint source and by the type of pollutant. In the Southeast region, the most widespread nonpoint sources are urban runoff (57 percent) and agriculture (62 percent), with silviculture and individual disposal systems also affecting roughly one-third of the basins. The most widespread pollution problems in the Southeast are bacteria, oxygen depletion, and high levels of nutrients. Toxics are judged to affect only 11 percent of the basins compared to only 32 percent

---

[1] For example, Kentucky's 208 Program is scheduled to be funded through August 1984.

TABLE 2-9: PERCENTAGE OF BASINS AFFECTED BY NONPOINT POLLUTION[a]

Pollutant	Geographical Region[b] Southeast	U.S. Total
Type of Nonpoint Source		
Urban runoff	57	52
Construction	2	9
Hydrologic modification	21	15
Silviculture	30	15
Mining	15	30
Agriculture	62	68
Solid Waste disposal	9	14
Individual disposal	40	43
Type of Pollution Problem		
Bacteria	66	61
Oxygen depletion	74	51
Nutrients	57	56
Suspended solids	34	54
Dissolved solids	4	30
pH	9	18
Oil and grease	4	9
Toxics	11	32
Pesticides	23	22

Source: U.S. EPA. 1978, 15-16.

[a] Percentage of basins affected where some (or all) stream segments have a problem that is not minor or insignificant, according to state officials. The total number of basins is: Southeast Region 47; U.S. 246.

[b] Note that the regional drainage basin groupings used here do not conform precisely to the boundries of the eight states. The Southeast Region includes the Southeast and Tennessee River basins.

nationwide. However, this relatively small percentage may result from lack of data.

Figure 2-5 shows "significant" nonpoint source water quality problems identified by state/regional study teams in the Second National Water Assessment.[1] In the Southeast, agriculture is a cause of significant problems in Mississippi and Kentucky. Along

---

[1] Note that Figure 2-5 does not include pollution problems of bacteria or oxygen depletion, or sedimentation due to soil erosion which is discussed later.

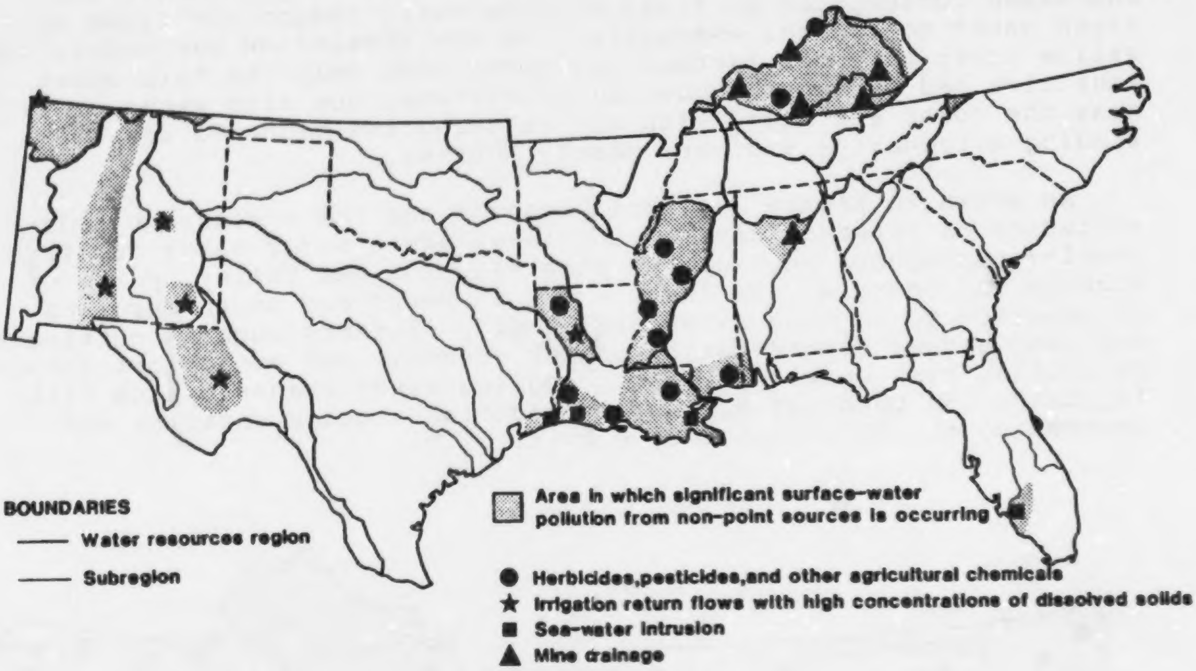

BOUNDARIES
Water resources region
Subregion
Area in which significant surface-water pollution from non-point sources is occurring
● Herbicides,pesticides,and other agricultural chemicals
★ Irrigation return flows with high concentrations of dissolved solids
■ Sea-water intrusion
▲ Mine drainage

Figure 2-5: Surface water pollution problems from nonpoint sources.

Source: U.S. Water Resources Council 1978b, pt. 3, 21.

with sediments washed off the land surface, herbicides, insecticides, and undesirable levels of fertilizers and other nutrients represent surface water problems. The National Residuals Discharge Inventory indicates that nationally about 33 percent of the oxygen-demanding loads, 66 percent of the phosphorus, and 75 percent of the nitrogen discharged into the streams in 1973 came from dispersed agricultural sources (U.S Water Resources Council 1978b, pt. 2, 23).

Kentucky and Alabama have identified acid mine drainage as a major problem. Where mining is or was prevalent, acid mine drainage pollutes both surface water and ground water supplies. Abandoned mines compound the problem since responsible parties are not always available to deal with the problem.

Intrusion of saline water into fresh surface water was identified as a major problem in southwest Florida. Impoundments and increased consumption of fresh surface water reduce the flows of fresh water to coastal estuaries. As the streamflow decreases, the saline water intrudes farther upstream. Not only can this upset sensitive and productive coastal ecosystems, but also water users near the coast are faced with either using the degraded water or finding alternative and more costly sources.

As shown in Figure 2-6, soil erosion and the consequent sedimentation of streams, rivers, and lakes are a major water quality problem throughout much of the Mississippi River Valley, parts of Alabama and Georgia, and large areas in North and South Carolina. In addition to serving as a carrier of pollutants such as nutrients and pesticides, sedimentation causes economic and ecological damage by ruining fish spawning areas, clogging river channels, and filling lakes and reservoirs, thereby reducing storage capacity and shortening the life of the reservoir.

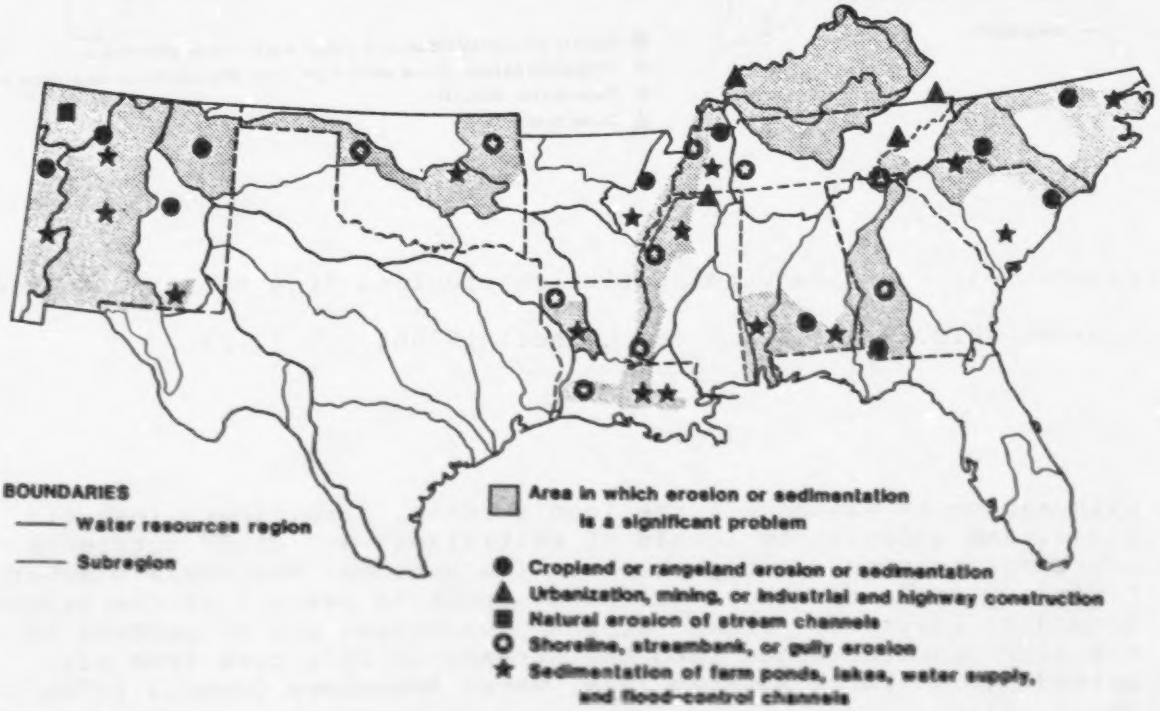

BOUNDARIES
Water resources region
Subregion
Area in which erosion or sedimentation is a significant problem
● Cropland or rangeland erosion or sedimentation
▲ Urbanization, mining, or industrial and highway construction
■ Natural erosion of stream channels
○ Shoreline, streambank, or gully erosion
★ Sedimentation of farm ponds, lakes, water supply, and flood-control channels

Figure 2-6: Erosion and sedimentation.

Source: U.S. Water Resources Council 1978b, pt. 2, 48.

Spills of oil, oil products, and other hazardous materials are another important source of nonpoint pollution. Numerous hazardous material spills have been reported in recent years. For example, Figure 2-7 displays data for the Southeast on the number of transportation and nontransportation-related oil spills reaching various waterways. From January 1976 through September 1977, transportation related oil spills involved over 500 incidents and the release

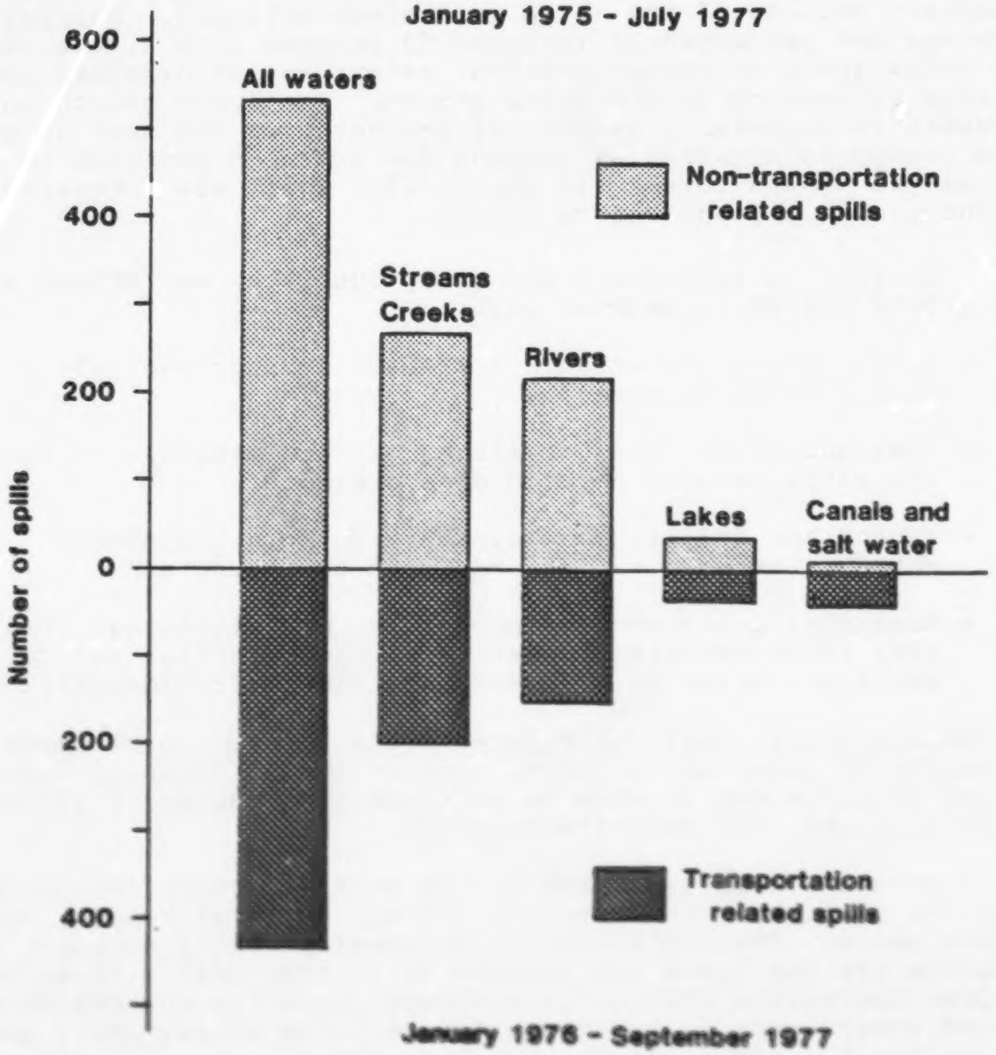


Figure 2-7: Oil spill data for the Southeast.

Source: U.S. EPA. 1978, 18.

of more than 1.5 million gallons of oil. Between January 1975 and September 19/7 there were over 400 nontransportation-related spill incidents involving about 0.5 million gallons (U.S. EPA. Reg. IV, 1978, 18-19).

Table 2-10 shows projections for the key driving forces behind nonpoint source pollution--population, agriculture, silviculture, and mining--and indicates the pollutants of primary concern. Population growth is important because of urban runoff and other nonpoint source activities (e.g., septic tanks, and construction). Agriculture and silviculture (lumber products) are particularily important because of the large land areas affected. Agricultural earnings are projected to increase 53 percent with little change in the crops grown or their location, except for an expected increase in rice production in the Delta states. Projected growth in lumber products is especially large--145 percent over the next 30 years. This growth is expected as demands for products continue to expand and as old growth forests in the Pacific Coast are harvested and second growth may not yet be mature.

Mining, including oil and gas production, can affect surface and ground waters in several ways:

- Land surface disturbance increases erosion and sediment loading to streams;
- Coal and other types of mining exposes minerals to air and water leading to acid mine drainage;
- Mining and drilling can disrupt aquifers and create pathways between saline and fresh aquifers; and
- Some mining and mineral processing activities can create very large amounts of waste with the potential for serious water pollution (e.g., phosphate mining in Florida).

As indicated previously in figures 2-5 and 2-6, mining impacts are currently an important problem, especially in Kentucky, and coal mining is projected to show an increase in earnings of almost 400 percent by the year 2010 (Table 2-10).

Trends and issues for two of the most important categories of nonpoint pollution, urban runoff and agricultural runoff, are discussed below. The EPA's highest national priority nonpoint source programs are for these two sources (U.S. EPA. Office of Water Program Operations 1981, 6). Although these two sources do affect ground water, especially in aquifer recharge areas, their greatest impact is on surface waters; for this reason, they are discussed in more detail in this chapter. Nonpoint sources which are generally more important to ground water are treated in Chapter 4. These include septic tanks and mining.

TABLE 2-10: SIGNIFICANT POTENTIAL NONPOINT POLLUTION SOURCES

Driving Forces	Earnings in the Southeast (millions of 1972 dollars)			BOD	Solids[a]	Coliforms and Other Bacteria	Nutri-ents	Heavy[b] Metals	High/Low pH	Organics[c]	Pest-icides
	1978	2010	% change								
Population[d] (urban runoff)	38.9 (1980)	83.9	+31	X	X	X	X	X		X	
Agriculture (01 and 02)	4,260	6,522	+ 53	X	X	X	X				X
Lumber Products (24)[e]	1,509	3,748	+145		X		X				X
Mining											
Coal Mining (11 & 12)	1,309	5,164	+399		X				X		
Crude Petroleum and and Natural Gas (13)	152	336	+121		X					X	
Metal Mining (10)	17	34	+100		X				X		
Nonmetal Mining, excluding fuels (14)	319	652	+104		X			X			

Sources: Nemerow 1978; U.S. Bureau of Economic Analysis 1980a, b.

[a] Includes suspended and dissolved solids and increased salinity.

[b] Includes mercury, zinc, copper, cadmium, and lead, etc.

[c] Includes hydrocarbons and toxic organic chemicals.

[d] Population is shown in millions of persons.

[e] Excludes pulp and paper earnings.

A. Urban Runoff

Urban rainfall runoff is a significant contributor to water quality degradation in heavily populated areas (U.S. EPA. 1978, 16), and as the Sunbelt population grows, its relative contribution to water pollution will likely increase. Almost every type of pollutant is found in urban runoff, with the most severe effects coming from suspended solids and heavy metals. Bacteria, BOD, COD, nutrients, and oil and grease also are associated with urban runoff. Pollutants come from such sources as air pollutants that settle in the streets, organic debris, animal wastes, litter, oil, and fertilizers and other lawn care chemicals. Urban runoff discharges may take the form of unsewered runoff, may be diverted to storm sewers, or to combined (rainfall and domestic) sewers.

Attempts to quantify current pollutant loadings or to project future trends in urban runoff are subject to considerable uncertainty. In the 1976 National Residuals Discharge Inventory, it was estimated that urban runoff contributes 1.7 million tons per year (tpy) of BOD and 30 million tpy of suspended solids. On a regional basis, it is estimated that urban runoff pollutant discharges in the Southeast are equal to 16 percent of the national total (U.S. EPA, Office of Research and Development 1980, 351).

Various nonstructural and structural control measures can reduce urban runoff pollution. Nonstructural measures, or Best Management Practices (BMPs) focus on prevention and include measures such as land use planning, use of natural drainage features, erosion controls, street repair and sweeping, collection system maintenance, control of litter, use of detention ponds, and on-site storage for runoff. Structural alternatives include conventional wastewater treatment practices, including primary and secondary treatment devices and high- and low-density area reservoirs (Metcalf and Eddy, Inc. 1977, 12-13). Although it is extremely difficult to quantify the benefits of a particular control option, BMPs are thought to provide faster results and better protection at lower costs than structural alternatives. To be effective, BMPs need to be used on a large scale basis (U.S. EPA, Office of Research and Development 1980, 346-47).

Because the Southeast is projected to have the largest absolute increase in population over the next 30 years, it is expected to have the largest increase in urban runoff pollution. These projections are uncertain, and actual pollution levels will depend on specific land use patterns and control measures. If it is assumed that increases in urban runoff loadings are directly proportional to urban population increases, then improved structural or nonstructural controls would be required in order to maintain 1975 pollution discharge levels (U.S. EPA, Office of Research and Development 1980, 353).

In an attempt to improve the control of urban runoff, the EPA instituted the Nationwide Urban Runoff Program. Twenty-eight urban areas were selected for data collection to assess urban nonpoint source problems and evaluate the effects of these sources on receiving water quality. The program will also evaluate BMPs which could be used to control pollution from urban runoff. Most of these prototype projects were to be completed between FY 81 and FY 83 (U.S. Council on Environmental Quality 1980, 135; U.S. EPA, Office of Water Program Operations 1981, 9). Due to project delays, only about one-third of the prototype projects have been completed to date (Tuller 1982). At least four of the prototypes are located in the Southeast (Myrtle Beach, South Carolina; Tampa, Florida; Winston-Salem, North Carolina; and Knoxville, Tennessee).

B. Agricultural Runoff

In rural areas, agriculture--irrigated and nonirrigated crop production and animal production--is the main nonpoint source of water pollution. Pollutants of concern include sediments, nutrients, pesticides, dissolved solids (salinity), and bacteria. As agricultural production grows and practices change, they can have a significant affect on water quality. As described earlier in Table 2-9, agricultural activities have been estimated to currently affect water quality in 62 percent of the basins in the Southeast.

Nonpoint source water pollution from agricultural activities can be controlled most effectively through the use of BMPs. For crop production in particular, proper land use and agricultural management practices are the keys to protecting water quality. Erosion and sediment loads can be reduced by use of terraces, diversions, strip cropping, contouring, grassed waterways, no-till farming, and/or crop rotations. Nutrient releases can be reduced by improved planning of fertilizer applications. For example, alternating production of nitrogen-fixing crops with crops requiring heavy fertilization can reduce the long-term average quantity of nitrogen that must be applied to soil. For pesticides, as with nutrients, BMPs must include consideration of timing, type, amount, and method of application. These control measures can be used in conjunction with integrated pest management (Thronson 1978).

The particular BMPs to be used depend on site-specific conditions and their effects on nonpoint source pollution are highly variable from crop to crop and from locality to locality. Thus, it is difficult to generalize about reductions in sediment and other pollutant loads to be expected from the adoption of BMPs (U.S. EPA, Office of Research and Development 1980, 358). As discussed previously in connection with point sources, there has been little effort to assess long-term water quality trends associated with the shifting agricultural practices. This suggests an important research need.

However, agricultural water pollution trends have been analyzed in Environmental Outlook 1980 (U.S. EPA, Office of Research and Development 1980, 364-85). Although many potential sources of error exist which threaten the accuracy of the estimated discharge levels, the projections indicate potential agricultural pollution and some of the factors contributing to these changes.[1] Some of the key findings for the Southeast are:

- Soil Loss: Soil loss, and hence sediment, would increase about 20 percent without any improvements from the use of BMPs. However, it is estimated that BMPs can reduce soil loss per acre by 30 to 50 percent (USDA, SCS, 1978). If such measures were applied region-wide, net discharges of sediment could actually be reduced by 2000.

- Nutrients: Discharges of nutrients (nitrogen, phosphorus, and potassium) are projected to increase substantially --about 50 percent for nitrogen and 100 percent for phosphorus and potassium. Increased soybean production is projected to account for a substantial share of the increased nutrient loadings.

- Pesticides: Gross discharges of all pesticide (herbicides, insecticides, and fungicides) are projected to increase about 40 percent. Although the quantities of pesticides are much smaller than other pollutants, they are potentially more important because of their toxicity. Although small in tonnage, discharges of fungicides are projected to show the greatest relative increase due to increased use per acre on potatoes and soybeans and larger soybean acreage. Herbicide use is increasing because of the need for better weed control associated with shifts to conservation tillage methods.

In sum, water pollution from agricultural activities is currently widespread in the Southeast and agricultural production is projected to increase. At the same time, considerable uncertainty exists about the effectiveness of controls; also, most control programs are voluntary and implementation barriers occur because of their expense. Approximately 30 prototype agricultural projects and 13 Rural Clean Water Program projects, supported by the EPA and the U.S. Department of Agriculture, are expected to be completed between FY 81 and FY 83. These prototype projects are selected to provide answers to key questions involving cause/effect relationships, cost effectiveness of controls, and fiscal/financial arrangements. The overall goal is to build a national nonpoint source control data base (U.S. EPA, Office of Water Programs Operations 1981, 9). Thus, considerable uncertainty exists about water pollution trends from agricultural practices in the Southeast and this is likely to be a continuing problem.

---

[1] The projection methodology (p. 359) used the following factors: crop production forecasts projected within the economic module of Strategic Environmental Assessment System; crop yield forecasts from U.S. Department of Agriculture; annual erosion estimates per acre by crop and soil typecalculated using estimated rainfall; soil erodibility and topography; crop management factors and conservation practices using the"universal soil loss equation"; sediment delivery ratios base on the size of the drainage area; and pesticide and fertilizer aplication rates by crop based on projected trends for the USDA.

2.4.3 Water Availability

Adequacy of water supplies to meet expanding industrial and population needs is a concern in many rapid growth areas. Water availability is a well-recognized problem throughout the West and Southwest, but often is not considered a general problem in the Southeast. However, three factors challenge this notion. First, although water supplies may be adequate on a regional basis, there may be serious difficulties in providing the water where it is needed. For example, counties with abundant water supplies have often been hesitant to share this water with neighboring counties, because the water offers a competitive advantage in attracting economic development. Under riparian water law, water transfers outside natural drainage areas also can be legally difficult. This is related to the second factor; institutional water management capacity, which is discussed separately in Section 2.4.4. The third important factor is the relationship between water quality and water availability; many studies on future water availability do not adequately consider this relationship. As described in the previous two sections of this chapter (2.4.1 and 2.4.2), many areas are experiencing water quality problems from point and nonpoint source pollution of surface and ground water. Thus, water availability could be a more important problem than suggested by only considering data on total volumes of water, since water quality degradation will limit the future uses of many water supplies and increase the costs of treatment.

Examples of water availability problems can be seen in Figure 2-8, which shows general areas in the Southeast where ground water is being pumped in excess of recharge.[1] Areawide problems exist along the Lower Mississippi (Arkansas, Mississippi, and Louisiana) and along the coast of North Carolina. In addition, more localized

---

[1] This figure, produced by the Water Resources Council, is intended only to indicate general ground water availability problems region-wide. It does not necessarily reflect a range of specific problems in each of the states.

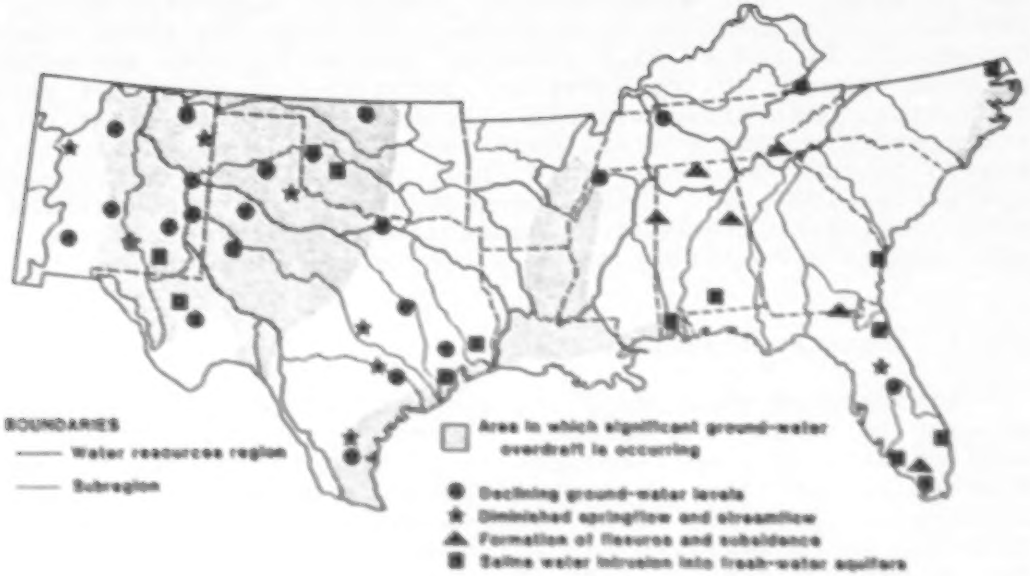

BOUNDARIES
Water resources region
Subregion
Area in which significant ground-water overdraft is occurring
● Declining ground-water levels
★ Diminished springflow and streamflow
▲ Formation of fissures and subsidence
■ Saline water intrusion into fresh-water aquifers

Figure 2-8: Ground water overdraft and related problems.

Source: U.S. Water Resources Council 1978d.

problems are particularly noticeable in Florida and parts of Alabama. Thus, although total quantities of surface water and ground water in the Southeast are much larger than current demands, numerous instances of over-reliance on limited ground water resources can be found. Several problems can result from ground water overdraft. Municipalities depending on ground water may face water shortages and increased pumping costs. Pumping of fresh ground water can cause saltwater intrusion and gradual reduction of surface flows in down-stream reaches. Land subsidence also ocurrs in many of these areas.

As an example of the relationship between water quality and availability, consider how ground water contamination can cause availability problems, especially since ground water is a major source of drinking water both nationally and in the Southeast. For example, in 1970, 67 percent of the population in the Southeast relied on ground water as a source of drinking water; in rural areas 98 percent of the population depended on ground water (see Chapter 3 for more detailed information on ground water use). Concern over the quality of drinking water has heightened over the last decade as improved analytical techniques have been used to identify toxic organic compounds and trace metals not previously detected in drinking water supplies. For example, in one recent survey trichloroethylene (TCE), a widely used solvent and degreaser which produces cancer in mice, was detected in 8 percent of the wells tested in the southeastern states (U.S. Council on Environmental Quality 1980, 94). Such findings have raised serious health concerns; furthermore and dealing with trace levels of toxic substances in drinking water can be very expensive. Thus, provision of safe drinking water supplies in the Southeast and nationwide will become an even more critical issue in the future.

Water availability problems also will be exacerbated by increased competition for water which will occur in many areas already experiencing multiple water resource problems. As identified in Section 2.3, this includes the industrial growth of chemicals in the South Atlantic-Gulf region, primary metals in Kentucky and Tennessee, paper products in the South Atlantic-Gulf, and petroleum refining in the Lower Mississippi region. Increased agricultural production for food export and biomass development is expected to occur in many parts of the study area, and large population increases are projected for Florida and along most of the Gulf coast.

In summary, increased competition for water and water quality protection are important factors to most southeastern states. Water resource limitations could force restrictions in the level of growth. States and local governments will need to enhance their capacity to manage water resources in order to avoid limitations on growth and development and to preserve adequate quality of water resources.

2.4.4 Water Management Capabilities

Much of the discussion in this chapter suggests that more active water resource management will be needed in the Southeast. Although active water management does exist in some areas of the Southeast, it is a relatively recent development. In fact, historical water abundance in this area has led to the widespread use of the riparian water system which allows relatively uncontrolled water withdrawals. However, increased concern over water quality problems and new demands resulting from population growth, irrigated agriculture, and industry are likely to create more stress on water resources.

Thus, in many parts of the Southeast the availability of adequate water supplies will be an important factor affecting growth. For example, municipalities are facing increased responsibilities for provision of water supply and protection of water quality with fewer resources. The rapid metropolitan growth throughout much of the Southeast (Science and Public Policy 1982, Ch. 3) will increase these municipal water management problems. Industries which require reliable water supplies may find expansion more costly because of the need to develop or transport water, or they may find growth to be impossible in some areas.

Improved water management can be accomplished in a variety of ways, including development of water resources, more efficient water use, improving institutional capacities, and improving information about water resources. Regardless of the specific strategies chosen, it is apparent that states and localities will become increasingly responsible for designing and financing new initiatives.[1] In order to meet this challenge, states and localities will first need to identify and assess the severity of their problems before they can select water policies appropriate to the growth pressures facing them. Among the specific needs in this regard are to assess:

- The adequacy of both riparian and appropriation systems for managing water conflicts;
- The adequacy of organizational arrangements affecting water resources, including whether fragmented or centralized arrangements are more appropriate;
- Alternative strategies for better integration of quality and availability concerns in water resource planning and decisionmaking;
- The adequacy of information bases about water resources, including monitoring of ground water quality, knowledge of current uses of water, and future trends in water quality;
- The potential for interstate conflicts over surface and ground water resources and whether new interstate arrangements are needed for emerging problems; and
- The adequacy of current policies to protect instream flow needs, including hydroelectric power generation, navigation, recreation opportunities, waste assimilation, maintenance of ecosystems, wetlands, and aesthetic qualities.

With regard to ground water, few states in the Southeast have developed ground water management systems, largely reflecting the historical abundance of the resource. Options for example managing ground water include, for example, designating critical areas where the available supply is being rapidly depleted or where continued withdrawals could lead to contamination through the intrusion of brackish water. Once areas are designated, a state, local, or regional agency can be empowered to regulate ground water use by establishing maximum pumping rates, apportioning the existing supply, closing the aquifer to new uses, or scheduling uses. Four states (Florida, Georgia, South Carolina, and North Carolina) have such designated areas and one other (Mississippi) is authorized to establish such areas. Conjunctive management--the recognition of surface and ground water interrelations and coordination of their use--can also be used to improve state management capacity. Ground water management options are treated in more detail in chapters 6, through 9.

---

[1] This trend toward increased state responsibility was begun under the Carter Administration and continues in the Reagan Administration. Garrey Carruthers, Assistant Secretary of Interior for Land and Water Resources, recently said that states would be left to their devices, regardless of cost (Bean 1981).

2.5 SUMMARY

This chapter has provided a brief overview of water resource uses and concerns in the southeastern United States. Table 2-11 summarizes water problems and issues in terms of the causal factors, the nature and seriousness of the problems, and the policy problems and issues created.

Among the most important driving forces affecting water are: (1) increased agricultural and silvicultural production; (2) continuing population increases, particularly in Florida and in the Gulf and South Atlanta coastal areas; (3) expanded energy development; and (4) growth of several industries which have large water requirements and/or large waste streams, particularly chemicals, pulp and paper, primary metals, and petroleum refining. In terms of water use, these driving forces may not, by themselves, create water shortages, but their multiple effects will stress water supply capabilities. Many localized areas are already experiencing supply difficulties, such as ground water overdraft. Water availability also depends not only on the total quantities of water used, but on the quality of that water. For example, contamination of ground water by toxic substances is a threat to drinking water supplies. In the Southeast, ground water supplies drinking water for 67 percent of the urban population and 98 percent of the rural population. Determination of the risks to human welfare and to other ecologic systems will be a difficult and long-term problem, yet extremely important to our ability to effectively manage natural resources.

In terms of water quality, the extensive pollution control programs developed largely in the 1970's are beginning to have an impact. If these efforts continue, even with population and industrial growth, the discharge of many pollutants should decline. Also, realization of many of the threats to ground water quality

TABLE 2-11: WATER ISSUES CHARACTERIZATION MATRIX

Impact or Problem	Causal Factors	Type of Problem Created	Duration	Pervasiveness	Magnitude/ Seriousness	Policy Problems and Issues
Point source pollution	Population growth Industrial, growth - Pulp and Paper Mills - Chemicals - Petroleum Refining - Primary Metals - Fabricated Metals - etc.	• Human Health • Ecological • Economic • Aesthetic	Both a current problem and a serious future problem as population and industry grow.	Currently a widespread problem. Municipal point sources seriously affect 91 percent of the basins in the Southeast. Industrial point sources seriously affect 74 percent of the basins.	By meeting planned discharge standards, projections indicate total discharges will decline in the future for some pollutants, but will increase for others. However, such projections are uncertain and few studies have attempted to project long-term water quality trends. Also, the economic costs of meeting existing or planned standards will be high.	• It may not be possible to meet existing or planned water quality standards in some areas with concentrated industrial population growth and/or low stream flows. • There is uncertainty as to the future federal role in assisting municipalities in constructing sewage treatment plants. • Water quality standards and monitoring networks do not adequately address toxic pollutants in most states.
Nonpoint source pollution	Agricultural runoff Urban runoff Septic tanks Mining runoff Silvicultural runoff Hazardous material spills	• Human Health • Ecological • Economic • Aesthetic	Both a current problem and a future problem, especially due to growth in agricultural production and urban development.	Currently a widespread problem. Agricultural and urban runoff seriously affects 62 and 57 percent of the basins in the Southeast respectively.	The most serious pollution problems from nonpoint sources are bacteria, BOD and COD, suspended solids (especially soil erosion), nutrients, and pesticides. Nonpoint sources are frequently the most common cause of ground water contamination. As urban population and agricultural production grow, nonpoint source pollution is likely to become worse.	• Although nonpoint source pollution is widespread and difficult to control, no broad-based regulatory program exists. • More research will be needed to better define the extent of nonpoint source pollution and the effectiveness of alternative controls (e.g., soil conservation practices and integrated pest management).

(continued)

TABLE 2-11: (continued)

Impact or Problem	Causal Factors	Type of Problem Created	Duration	Pervasiveness	Magnitude/ Seriousness	Policy Problems and Issues
Water availability	Increased agricultural production Growth of Industry - Chemicals - Pulp and Paper - Primary Metals - Electric Power Generation - Etc. Population Growth	• Economic • Ecological • Aesthetic	Ground water overpumping is an existing problem in several areas. Long-term problem in the Southeast. Once ground water is contaminated, it can be essentially irreversible.	The coastal areas will likely face the most serious problems. There is no comprehensive data base on ground water quality. However, based on intensive local studies, ground water contamination is more widespread than previously thought.	Water shortages and treatment/distribution problems could affect the economic growth and population stability of the region. In some areas, ecological damage to aquatic ecosystems could be irreversible. Recent discoveries of trace levels of toxic pollutants creates human health concerns.	• Riparian water laws create many barriers to improved water resource management. • Water quality and water quantity concerns are seldom integrated. • Few mechanisms for intergovernmental cooperation exist. • Research and regulatory programs to protect vital ground water resources lag several years behind those for surface water.
Water management	Rapid expansion or demands for water Increasing water quality problems Limitations in existing institutions	• Political • Economic	Already a major issue in some areas (e.g., Florida). Likely to become increasingly important important throughout the Southeast in the 1980's.	Problems will be pervasive across the region. Areas likely to feel most immediate need for improved management are the states of the South Atlantic coast.	Water is central to the growth capacity of each state. Without improved management, growth could be restricted in some areas.	• Revisions in water management capabilities are likely to be difficult where water has historically been abundant. • Interstate cooperation to deal with ground water problems and river basin problems may be very difficult. • State and local governments will have more responsibility and fewer resources to deal with these problems.

has increased research and regulatory programs which should help to reduce these threats. On the negative side, several factors are likely to cause further declines in water quality in some areas. Even with expensive pollution control facilities, point and nonpoint sources could deteriorate water quality in areas of concentrated growth. As urban population and agricultural production expand, nonpoint sources of pollution are likely to increase, depending on the extent to which various control measures, such as soil conservation practices, are applied. Other projected growth activities could exacerbate nonpoint source pollution problems, including expanded coal mining, oil and gas production, septic tanks, and spills of hazardous materials.

The expanded use of water and the potential for water quality degradation will increase the importance of water planning and management programs. This need is occurring at a time when state and local governments may find themselves in the position of having to take on a greater share of the financial burden for both water quality protection (e.g., municipal sewage treatment plants and water quality planning) and water supply projects (e.g., dams and reservoirs). Many state and local governments in the Southeast will need to improve their capacity to actively manage water resources. In part, this is because much of the region traditionally has been water rich; thus, comprehensive water management systems have not been developed. The riparian system, based on water abundance, creates many barriers to managing a scarce resource. In addition, regulatory systems to protect ground water systems and instream values generally have been slow to develop. Virtually no cooperative intergovernmental mechanisms exist for resolving emerging issues affecting multi-state river basins or aquifer systems. Thus, one of the most serious questions about economic and population growth in the Southeast over the next two decades will be the adequacy of water resources to meet increasing demands.

REFERENCES

Bean, Covey. 1981. "States Told to Expect No Aid from Feds on Water Woes." The Daily Oklahoman, December 2.

Dolgin, Erica L., and Thomas G. P. Guilbert, eds. 1974. Federal Environmental Law. St. Paul, MN: West Publishing Co.

Geraghty, James J., et al. 1973. Water Atlas of the United States. Syosset, NY: Water Information Center.

Heath, Ralph C. 1982. "Classification of Groundwater Systems of the United States." Ground Water 20:393-401.

Luken, R. A., D. J. Basta, and E. H. Pechan. 1976. The National Residuals Discharge Inventory. Washington, D.C.: National Commission on Water Quality. As cited in U.S. EPA, Office of Research and Development 1980, 344.

Metcalf and Eddy, Inc. 1977. Urban Stormwater Management and Technology: Update and User's Guide. As cited in U.S. EPA, Office of Research and Development 1980, 346-47.

Nemerow, Nelson L. 1978. Industrial Water Pollution: Origins, Characteristics, and Treatment. Reading, MA: Addison-Wesley.

Science and Public Policy Program. 1983. Southern Regional Environmental Assessment: Environmental Status Report. Washington, DC: Environmental Protection Agency, Office of Research and Development.

Shepherd, A. D., et al. 1980. State Water Use and Socioeconomic Data Relating to the Second National Water Assessment. Oak Ridge, TN: Oak Ridge National Laboratory.

Solley, Wayne B., Edith B. Chase, and William B. Mann. 1983. Estimated Use of Water in the United States in 1980. Geological Survey Circular 1001. Washington, DC: Government Printing Office.

Thomas, Harold E. 1951. The Conservation of Ground Water: A Survey of the Present Ground Water Situation in the United States. New York: McGraw-Hill.

Thronson, R. E. 1978. Nonpoint Source Control Guidance: Agricultural Activities. Washington, D.C.: U.S. Environmental Protection Agency. As cited in U.S. EPA, Office of Research and Development 1980, 356.

Tuller, Stewart. 1982. U.S. Environmental Protection Agency, Water Planning Division. Personal communication, October 14.

United Nations. Department of Economic and Social Affairs. 1976. Ground Water in the Western Hemisphere. Natural Resources/ Water Series, no. 4. New York: United Nations.

U.S. Department of Agriculture (USDA). Soil Conservation Service. 1979. Environmental Impact Statement: Rural Clean Water Program. Washington, DC: Government Printing Office.

U.S. Council on Environmental Quality (CEQ). 1979. Environmental Quality: Tenth Annual Report. Washington, DC: Government Printing Office.

______. 1980. Environmental Quality: Eleventh Annual Report. Washington, DC: Government Printing Office.

U.S. Bureau of Economic Analysis. 1980a. BEA Industry Earnings Data. Washington, DC: Government Printing Office.

______. 1980b. Regional Economic Projections. Washington, DC: Department of Commerce.

U.S. Environmental Protection Agency (EPA). 1978. National Water Quality Inventory: 1977 Report to Congress. Washington, DC: Government Printing Office.

______. Office of Research and Development (ORD). 1980. Environmental Outlook 1980. Washington, DC: Government Printing Office.

______. Office of Water Program Operations. 1981. Water Quality Management Five Year Strategy: FY-82 Baseline. Washington, DC: Environmental Protection Agency.

______. Region IV. 1978. Southeast Environmental Profiles, 1977. Atlanta, GA: Environmental Protection Agency.

U.S. National Oceanic and Atmospheric Administration (NOAA). 1980a. Local Climatological Data, Annual Summary with Comparative Data: Miami, Florida. Asheville, NC: National Climatic Center.

______. 1980b. Local Climatological Data, Annual Summary with Comparative Data: Atlanta, Georgia. Asheville, NC: National Climatic Center.

U.S. Water Resources Council. 1978a. The Nation's Water Resources 1975-2000. Vol. 1, Summary. Second National Water Assessment. Washington, DC: Government Printing Office.

______. 1978b. The Nation's Water Resources 1975-2000. Vol 2, Water Quantity, Quality, and Related Land Considerations. Second National Water Assessment. Washington, DC: Government Printing Office.

______. 1978c. The Nation's Water Resources 1975-2000. Vol. 3, Analytical Data Summary. Second National Water Assessment. Washington, DC: Government Printing Office.

______. 1978d. The Nation's Water Resources 1975-2000. Vol. 4, Texas-Gulf Region. Second National Water Assessment. Washington, DC: Government Printing Office.

______. 1978e. The Nation's Water Resources 1975-2000. Vol. 4, Second National Water Assessment. South Atlantic-Gulf Region. Washington, DC: Government Printing Office.

______. 1981. State of the States: Water Resource Planning and Management; Ground Water Supplement. Washington, DC: Water Resources Council.

Zuranski, Ann. 1978. Summary Appraisals of the Nation's Ground-Water Resources--Tennessee Region. U.S. Geological Survey Professional Paper 813L. Washington, DC: U.S. Geological Survey.

CHAPTER 3

CASE STUDIES IN THE SOUTHEAST

3.1 INTRODUCTION TO THE CASE STUDIES

The water resources of the Southeast can be characterized at several geographic scales: region-wide characteristics such as the Southeast's generally abundant rainfall and continuously flowing streams; subregional characteristics of river basin or ground water resource regions; and local characteristics such as those of counties or segments of watersheds.

In response to these different geographic scales, and in order to provide an integrated perspective, the methodological approach to regional environmental assessment developed by the Science and Public Policy Program involves three levels of analysis:

- Region-Wide Analysis, intended to provide the broadest overview of region-wide trends and policy issues;
- Subregional Analysis, still intended to provide a broad perspective, but narrowed to geographical areas of particular significance (e.g., river basins, ecological regions, or coastal areas);
- Site-Specific Analysis, intended to provide a detailed, integrated analysis of driving forces, environmental problems, and social/institutional structures within a localized geographical area.

Analysis at these three levels is complementary; for example, the broad regional overviews of water resources included in Chapter 2 and described in more detail for ground water problems and issues in chapters 4 and 5 are useful in identifying important locations for detailed analysis and, in turn, assessment of several site-specific areas helps to develop an understanding of the entire region.

Each smaller scale of analysis provides a more detailed view of water resources problems and issues. Because ground water problems and issues are often localized, selecting site-specific areas for more detailed review becomes an important activity that affects how problems are characterized in the region and what policy options might be used to mitigate identified problems.

Three criteria are used to select site-specific study areas:

- The set of sites should be representative of the key driving forces, environmental problems, and geographical characteristics of the overall study area;
- Each site should involve identifiable growth and environmental concerns, either currently or in the future; and
- The set of sites should be diverse; they should allow the research team to understand key locational differences which influence the nature of environmental impacts--for example, how do impacts resulting from similar scales of residential and commercial development differ from location to location?

Applying these criteria to this study of ground water in the Southeast, the research team and personnel from the U.S. Environmental Protection Agency (EPA) Region 4 personnel, selected four sites:

- Columbia, South Carolina: this two-county area (Lexington and Richland counties) is representative of several rapidly growing urban areas located along the southeastern Fall Line, the divide between the Atlantic Coastal Plain and Piedmont regions.
- Georgetown, South Carolina to Wilmington, North Carolina: this four-county area (Georgetown and Horry counties, South Carolina, and Brunswick and New Hanover counties North Carolina) is on the South Atlantic Coast. It is representative of several rapid growth areas in the Atlantic Coastal Plain ground water region highly dependent on ground water.
- Biscayne Aquifer, Florida: this heavily populated two-county area (Dade and Broward counties) is completely dependent on ground water and has been dealing with major ground water management problems for many years.
- Henry County, Georgia: this is a rural, but growing county in the Piedmont ground water region. There has been little attention to the potential for ground water to support future growth in this area.

Certainly, four areas cannot fully represent the variety of conditions that exist across the Southeast. However, taken together these four cases do represent a considerable range on several key variables, including: (1) hydrological conditions; (2) current dependence on ground water; (3) level of study and attention to ground water problems and issues; (4) population concentrations; and (5) institutional capacities to deal with ground water issues.

Each case study was undertaken by an individual member of the Science and Public Policy Program and each person devoted between one and two person-months to the effort, including three to five days spent collecting data and interviewing parties-at-interest in the study area. Each case study addressed the following major topics:

- Description of Current Status: geography, the current population and economic base, water use and supply patterns, hydrology and the existing institutional systems concerned with water quantity and quality;
- Future Trends: population and economic growth trends and projections (especially those important to water use or potential water quality degradation), and future water plans;
- Current and Emerging Problems and Issues: point and nonpoint source pollution problems; management or institutional issues involving either ground water supply or quality protection; and ground water monitoring or data management problems; and
- Policy or Management Options: identification of options which are being proposed or which local parties identified as being suitable; possible options which the research team member feels may be particularly appropriate to this area.

Findings from these studies have been prepared in four separate reports; these reports will not be published separately. Rather, the remainder of Chapter 3 summarizes the descriptive material for the four cases. The problems and issues findings are integrated into chapters 4 and 5, and the identification of policy options has informed the policy analysis effort in chapters 6 through 9. The subsequent sections discuss each of the study areas, first by describing the existing setting and trends, and then by identifying major problems and issues.

3.2 COLUMBIA, SOUTH CAROLINA STUDY AREA

3.2.1 Status and Trends

Columbia, the capitol of South Carolina, is located in Richland County with surrounding population also located in Lexington County. This two county area lies at the interface of the Piedmont Plateau and the Coastal Plain (see Figure 3-1) known as the "Fall

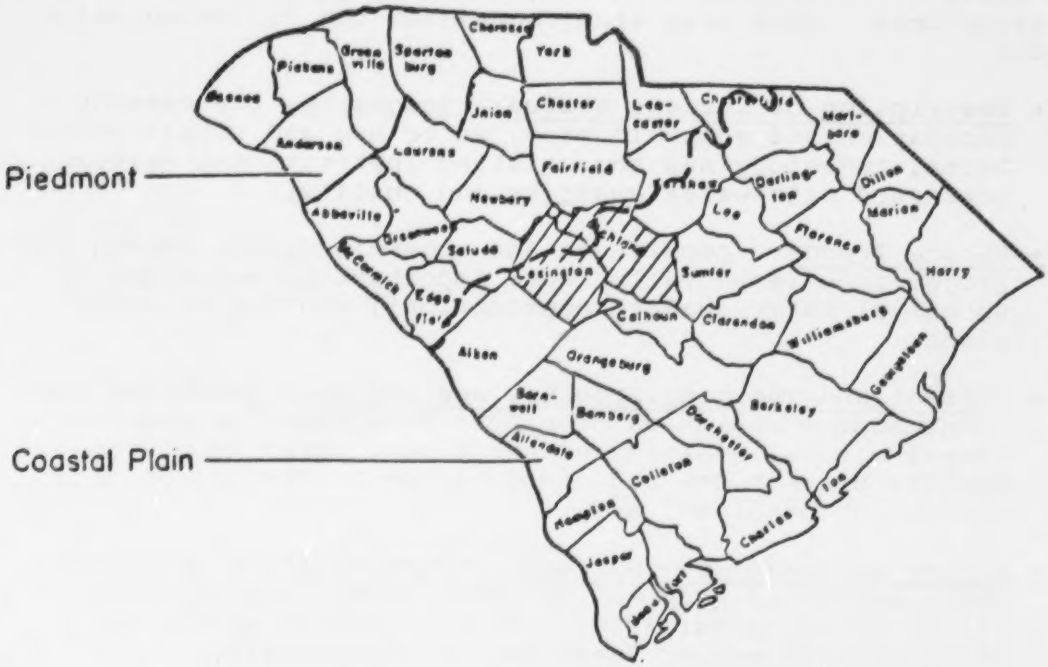


Figure 3-1: County Map of South Carolina, highlighting the Fall Line location of Lexington and Richland Counties.

Source: Adapted from Coastal Plains Regional Commission 1979.

Line" where the rapids and low falls on the southeastward flowing rivers impede upstream navigation. The changes from igneous and metamorphic rocks of the Piedmont to the unconsolidated sediments of the Upper Coastal Plain (or Sand Hills) present significant geologic variations which directly affect the availability and quality of the ground water. The Columbia area, the largest urban complex in the state, is experiencing problems similar to other growing southeastern cities located along the Fall Line. In particular, both counties face many water resource issues created by a rural setting with limited infrastructure for meeting expanding suburban demands.

A. Population and Economics

The total population for the two counties grew by 47 percent during the past 20 years, reaching a total of 410,088 persons in 1980 (see Table 3-1). This increase is much higher than the 31 percent growth for the entire State of South Carolina. However, the most dramatic increases in the two counties have occurred in areas that were rural in 1960 and are now part of the expanding urbanized areas. Some of these areas have experienced population growth of well over 100 percent over the past 20 years (Central Midlands Regional Planning Council 1982).

The regional planning agency projects higher than average population growth rate to continue with a 64 percent increase by the year 2000 for a total population of 671,000 (see Table 3-1). This exceeds the Bureau of Economic Analysis (BEA) population projections for the Columbia area which indicate a possible population range from 489,242 to 509,576 by the year 2000. However, the U.S. Dept. of Commerce, Bureau of Economic Analysis (BEA) projections for 1985 (414,210 to 423,244) are very close to the 1980 Census figure for Columbia (410,088), suggesting that the BEA projections

TABLE 3-1: COLUMBIA, SOUTH CAROLINA METROPOLITAN AREA HOUSING AND POPULATION TRENDS

	1960[a]	1970[a]	1980[a]	2000
Total Population	260,828	322,880	410,088	671,000[b]
Total Year Round Housing Units	68,677	93,980	142,914	256,000[c]
Average Persons Per Household	3.63	3.30	2.83	2.58[c]

Source: Central Midlands Regional Planning Council 1982.

[a] 1960, 1970, and 1980 Censuses of Population and Housing, U.S. Department of Commerce, Bureau of the Census.

[b] Population Projections for the Central Midlands Region, Central Midlands Regional Planning Council, June 1977.

[c] Projections by the staff of the Central Midlands Regional Planning Council based on information presented in Projections of the Numbers of Households and Families: 1979 to 1995, Population Estimates and Projections Series P-25 No. 805, U.S. Department of Commerce, Bureau of the Census.

may slightly underestimate Columbia's current population growth (Central Midlands Regional Planning Council 1982; U.S. Bureau of Economic Analysis 1980).

Columbia enjoys a relatively diverse economy rooted in the historical development of the area. Thus, it has been somewhat sheltered from the full effects of recent economic downturns. In fact, several large industries are locating new plants in the Columbia area. For example, Sony has just chosen Columbia for its largest U.S. plant and others, such as Michelin Tire Co., United Technologies, and Union Camp have also begun construction or announced plans to locate in the area (Central Midlands Regional Planning Council 1982; Economic Development Commission 1982).

Table 3-2 illustrates both the diversity of the economy in the Columbia metropolitan area as well as the shift since 1960 in some sectors. The percentage of nonagricultural employment, for example, derived from services and government has increased from 38 percent in 1960 to 46 percent in 1980, while the contribution of manufacturing and construction has decreased from about 24 percent in 1960 to 20 percent in 1980 (Central Midlands Regional Planning Council 1982). The counties do not share equally in the economy, however. For example, in 1975 nearly 84 percent of the Central Midlands area's government jobs were in Richland County. About 41 percent of the area's manufacturing jobs were in Richland County. Both counties share similar types of industries, including machinery manufacturing and retooling, metalworking, chemicals and allied products, and textiles.

TABLE 3-2: COLUMBIA METROPOLITAN AREA NONAGRICULTURAL EMPLOYMENT

Category	Number Employed[a] (percent) 1960	1970	1980
Manufacturing	12,600 (18.1)	21,100 (19.0)	27,300 (15.1)
Construction	4,600 (6.6)	7,700 (6.9)	8,400 (4.6)
Wholesale/Retail	15,800 (22.6)	22,800 (20.5)	37,700 (20.9)
Finance/Real Estate/Ins.	5,000 (7.2)	7,100 (6.4)	13,800 (7.6)
Transportation/ Utilities	5,000 (7.2)	7,100 (6.4)	9,400 (5.2)
Services	9,000 (12.9)	14,600 (13.1)	27,200 (15.0)
Government	17,700 (25.4)	30,300 (27.2)	56,600 (31.3)

Source: Central Midlands Regional Planning Council 1982.

[a] South Carolina Employment Security Commission

Several constraints to industrial growth exist which may affect the economy of the area. Both counties lack industrial size water lines and municipal sewers outside the urbanized areas. This limitation on site development requires that industry must often develop individual water and sewage treatment services. State laws that protect incorporated areas and restrict water transfers together with the desire for local autonomy stymie efforts at consolidation of cities and towns to improve service delivery (Central Midlands Regional Planning Council 1982).

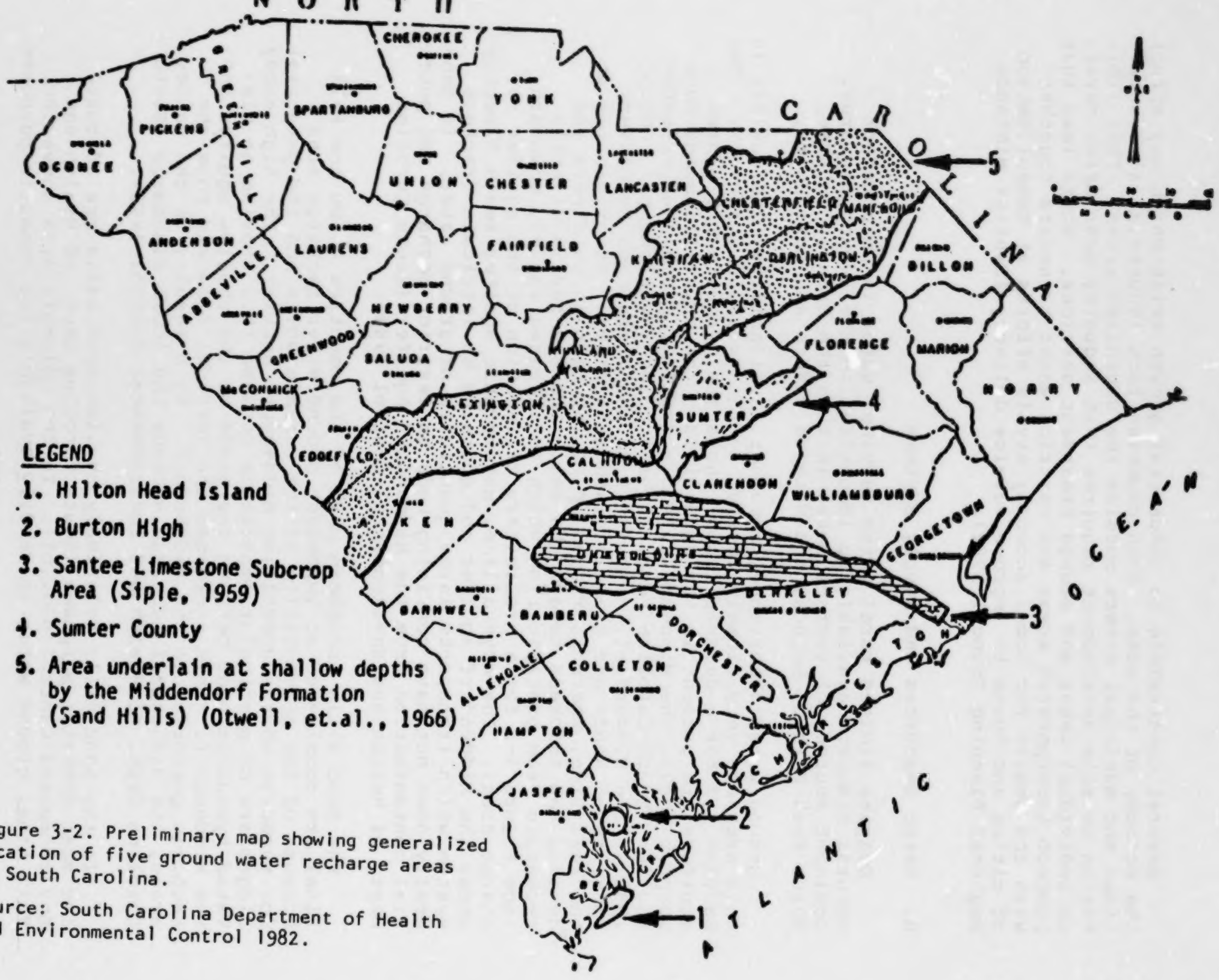
B. Water Resources and Supply Systems

Despite limited rural water service, water is an abundant natural resource available to industries in the two-county area. Dominant sources of surface water include the Broad, Congaree, North Fork Edisto, Saluda, and Wateree Rivers and Lake Murray.

Ground water occurrence, movement, availability, and quality in this area are very closely related to the geologic framework. (See Section 3.3 for a description of the state's aquifers). Three aquifers are present in the Sand Hills: the crystalline and metamorphic rocks, the Middendorf, and a shallow, perched water-table aquifer (South Carolina Dept. of Health and Environmental Control 1982). The Middendorf, also known as the Tuscaloosa Formation, consists of sands and gravels mixed with clays. It originates at the Fall Line, where it ranges up to 150 feet in thickness and deepens and thickens toward the sea. The aquifer is directly recharged from precipitation which infiltrates rapidly downward (see Figure 3-2 for a preliminary delineation of the aquifer recharge area). The crystalline, metamorphic aquifer rests directly under the Middendorf Aquifer and contains an intricate fracture system which transports large quantities of ground water. It generally does not have confining beds to restrict recharge and potential contamination from the Middendorf Aquifer (South Carolina Dept. of Health and Environmental Control 1982).

The Sand Hills (southern part of the counties below the Fall Line) are considered an important ground water recharge area because of the permeability of the surface soils and the potential for recharge to the underlying Middendorf Aquifer. The high sandy ridges are of particular importance because they provide an elevated hydraulic head between the sands of the shallow aquifer and the Middendorf. This increases the vertical flow and thus the recharge potential to the Middendorf. As a result, in the valley areas, the Middendorf recharge exceeds the local discharge (South Carolina Dept. of Health and Environmental Control 1982).

In the Sand Hills relatively shallow sand wells are adequate for most domestic purposes (South Carolina Dept. of Health and Environmental Control n.d.[b]). In the Columbia area above the Fall Line, ground water is readily available for domestic purposes



LEGEND

1. Hilton Head Island
2. Burton High
3. Santee Limestone Subcrop Area (Siple, 1959)
4. Sumter County
5. Area underlain at shallow depths by the Middendorf Formation (Sand Hills) (Otwell, et.al., 1966)

Figure 3-2. Preliminary map showing generalized location of five ground water recharge areas in South Carolina.

Source: South Carolina Department of Health and Environmental Control 1982.

(3 to 5 gallons per minute [gpm]) except in those parts of the Piedmont area where drilling sites are limited by small residential and lake lots. Wells supplying higher yields for small public systems and light industry (10-15 gpm) are available in both the igneous granites and metamorphic slates of the Piedmont. Highly variable yields up to 200 gpm occur on rare occasion, but average yields are 5-20 gpm. Excessive drawdown can occur and often results in high pumping costs. The quality of the ground water is also highly variable depending usually on rock type. That found in the unconsolidated sediment is typically of good quality. The major constraints to ground water use are low pH and alkalinity, high iron levels or high levels of natural radionucleides (South Carolina Dept. of Health and Environmental Control n.d.[b]).

In Lexington County, there are five water systems supplied by surface water and 186 supplied by ground water.[1] In Richland County, there are two surface water supply systems (for Columbia and Fort Jackson) and about 114 ground water systems.[2] Estimates of populations served by these systems suggest that well over one-half of the population of Lexington County is dependent on ground water for their drinking water supplies if domestic wells are included. In contrast, less than one-fourth of the Richland County population appears to be currently dependent on ground water for drinking water supplies. The City of Columbia expects to continue to use surface water, Lake Murray, for future water supplies and may extend its service delivery area through both counties. Depending on the extension of service delivery and the rate of population growth, it is conceivable that the proportion of the population dependent on ground water will decrease in the future. However, ground water is expected to be developed for drinking water supplies in the future in Lexington County. Industry in Lexington County will also continue to develop ground water as its water supply along the highway corridors. It is unlikely that ground water would be the major supply for the entire Columbia area in the future; however, the quality and location of those supplies have already had an impact on planning for growth and development in the area despite the abundance of surface waters.

---

[1] The surface water systems include the towns of Batesburg and Lexington, and the City of Cayce (Red Bank is supplied by Lexington). West Columbia gets its water from the Saluda River. Ground water wells supply the towns of Chapin, Pelion, Swansea, and Leesville, and the Gilbert-Summit Rural Water District and the Gaston Rural Communicy Water District. Most of the remaining well water systems (about 180) in Lexington County are privately owned (Central Midlands Regional Planning Council 1979).

[2] The City of Columbia water system has been using the Columbia Canal (an old mule/barge system) along the Broad River but has recently completed a new water plant on Lake Murray in Lexington County. The Fort Jackson Military Reservation is supplied by the City of Columbia, but supplements this with its own source in Forest Lake. Ground water systems include the town of Eastover and 113 other privately owned well water systems (Central Midlands Regional Planning Council 1979).

3.2.2 Problems and Issues in Ground Water Development

A. Fragmented Service Systems

The water problems in this two-county area are to a large extent occurring within the context of a state with fragmented agency responsibilities for water quality and quantity problem solving. In the Columbia metropolitan area, for example, there are over 300 agencies providing water service. This includes public and private agencies serving residential, industrial, and commercial customers. Only 14 of these agencies are public; however, the remaining private water systems often serve as few as 30 or less residences. Some of the smaller private systems are not approved by the State Department of Health Environmental Control; they do not have the capacity for fire flow, for example; and the rates charged to customers vary significantly. To contrast, the 14 public utilities together provide a combined capacity of 86.3 million gallons per day (mgd) while the existing private systems provide a capacity of about 5 mgd (Central Midland Regional Council 1979).

The Columbia urbanized area is developing several alternatives for dealing with inadequate private sewer systems. Most of these alternatives are variations of a basic requirement for users' fees to tie into the public system. Some disagreement seems to exist over whether these fees should protect the city from absorbing the costs or should be high enough to induce the private systems to turn their systems over to the city.

The office of the City Engineer of the City of Columbia has a long term contingency plan to provide water service for most of Richland, Lexington, and adjacent Fairfield counties. At present the City of Columbia serves about 210,000 people and, in the future, expects to serve as many 645,000 people requiring a capacity of about 200 mgd. A typical load is estimated to be 90 to 115 gallons per day per capita; the peak to date has been about 135 gallons per day per capita, including irrigation, swimming pools, etc. To prepare for large water demands, the city purchased 100 acres of lakefront property at Lake Murray for a water treatment plant with a potential supply capacity of 100 mgd. The city purchases its water from South Carolina Gas and Electric, a private utility which developed Lake Murray.

The city is implementing a computerized distribution system to increase flexibility of delivery and to save money. The city's electricity bill is about 750,000 dollars a month for water and sewage. This system can be used to reduce water pressure to save water rather than asking people to conserve water. The city depends on water revenues and thus is concerned that, if citizens voluntarily conserve too much water, the city could not be able to sustain adequate revenues without raising rates.

B. Lack of Intergovernmental Cooperation

The institutional interrelationships governing water quality management in the two-county area is complex from a legislative, financial, and political viewpoint. The major federal authority comes from from the Federal Water Pollution Control Act of 1972 as amended. The state authority is exercised in several different areas. For example, the state legislature creates the cities and counties and specifies the overall framework and legal powers for water quality management agencies. Moreover, the governor's office makes appointments to Public Service District Commissions in the area. However, the primary state responsibility for water quality management lies with the South Carolina Department of Health and Environmental Control. This agency issues permits for pollutant discharge, wastewater facility construction, solid waste disposal, well-drillers, etc. It also monitors streams and drinking water for pollutants.

The South Carolina Water Resources Commission (SCWRC) in the past has had little direct involvement with these two counties since its powers were limited to "capacity use areas" and general supply and demand issues (see Chapter 5). However, recent legislation requiring permits and reporting by major users and a more active stance toward planning may increase its involvment in the future.

Local units, including the two counties and numerous cities and towns, have participated voluntarily in the Central Midlands Regional Planning Council planning forum. However, construction and administration of water and sewer functions is an autonomous undertaking by most cities and towns. The most significant intergovernmental agreements for sewer treatment are those which the City of Columbia Metropolitan Treatment Plant has with West Columbia and the adjacent Fort Jackson military installation (Central Midlands Regional Planning Council 1979).

The only common source of revenue for these management agencies are tap fees, service charges, and federal grants through EPA. The most usual financing method is the issuance of revenue or obligation bonds which are then retired by service charges. Some improvements are also paid for indirectly through property taxes. However, in Lexington County, the residents have passed a referendum specifically prohibiting the use of property taxes for improvements on the county's water and sewer facilities, thus, effectively blocking further development of a central delivery system.

Currently, both counties appear to be resisting efforts of the City of Columbia to become the primary central delivery system for water and sewer facilities for the entire area. This resistance is tied in part to political concerns over past annexation efforts by Columbia.

As an example of a desire for local autonomy, in Lexington County, the cities of Leesville and Batesburg, located a few miles apart in a growth area, have not been able to coordinate efforts to supply water. Rather than purchase surplus water from Batesburg, officials in Leesville decided to develop ground water wells nine miles to the south despite considerable pumping costs.

The state has taken initiatives to improve management capacity. For example, in 1969 South Carolina enacted the Ground Water Use Act which authorized the South Carolina Water Resources Board to establish "capacity use areas" if studies indicated possible limited supplies for existing needs (Putt 1981). In 1981 the state enacted the South Carolina Water Use Reporting and Coordination Act (SCWRC) which authorized the SCWRC to develop regulations requiring the reporting of all water used, diverted, discharged, etc., in the state. The act is generally viewed as a tool for developing better information for planning both locally and state-wide.

Despite efforts at the state level to develop a better understanding of and management capacity for water supplies, most of the decisions on water resources continue to be made locally. In the Columbia area, the City of Columbia does its own planning and financing in conjunction with federal assistance. The county areas are spotted with municipalities and towns which are making autonomous decisions for controlling and developing supplies. Despite voluntary participation by many of these units in the Central Midlands Regional Planning Council as a forum for planning, efforts to develop a concensus on a long-range, coordinated plan for water supplies throughout the two-county area is not a reality. Generally, water supply problems in this area are political/institutional rather than physical ones. In other words, there will be sufficient water if quality standards are enforced and if governmental units are able to cooperate.

State laws do not require coordination of water supply planning or development and have no clear administrative mechanisms for resolving conflicts over use[1]. The potential exists for conflicts between governmental units and among private users over priorities for available water.

C. Ground Water Pollution Problems

Although the most persistent threats to ground water in this area of South Carolina seem to come from nonpoint sources, some threats to ground water may exist from discharge of inadequately treated sewage into streams. Although DHEC permits discharges into streams based on flow levels and monitors for fecal coliform, natural and industrial heavy metals, dissolved oxygen, and pH levels (Lumpkin 1982), testing for such substances as volatile organic chemicals is not routinely done (South Carolina Dept. of Health and Environmental Control 1982). In the metropolitan area, over 170 public, industrial, and private sewage treatment systems discharge directly into the Broad, Saluda, or Congaree rivers and their tributaries. Efforts to consolidate many of these discharge points to improve management of water quality through the development of interceptor lines and tie-ins have not proceeded as rapidly as planned five or six years ago. Instead, the trend has been for private sewer systems to remain independent. In 1978, metropolitan Columbia was ranked as the top water pollution problem area in South Carolina with the subbasin or drainage areas of the Broad, Saluda, and Congaree rivers also ranked in the top half (Central Midland Regional Planning Council 1979).

Nonpoint sources of pollution have become the major threat to ground water, especially in the Sand Hills region of the two-county area. In the urbanized areas of Columbia, stormwater runoff and industrial waste disposal are the predominant pollution sources. In the more rural areas, however, septic tanks, landfills, improper well construction, abandoned wells, and lack of adequate land use zoning all combine to produce serious threats to ground water quality.

Local contamination of wells has occurred occasionally with some orders issued to close domestic wells. Since no comprehensive assessment of the quality of ground water has been completed for either county, it is difficult to determine where untreated ground water is potable.

---

[1] In 1982, the Governor established the State Water Law Review Committee (S.C. Executive Order #82-18) out of concern for the fact that "....no clear authority or responsibility....for drought management exists" and "the state's existing legal and administrative structures may be inadequate to manage and resolve water conflicts...."

Attempts to deal with some of these problems have been met with opposition. For example, in Springdale, a Lexington County community partially dependent on ground water, citizens in 1980 voted down a plan to construct a federally funded interceptor line to extend sewer service despite persistent ground water contamination from poorly designed septic tanks during periods of heavy rain. Some reasons cited for the opposition included fear that sewer service would encourage the development of apartments, costs involved for tap-on and monthly use, and uncertainty over which areas would get early benefits from use (O'Boyle 1980). Indeed, attempts to develop central sewer service throughout Lexington County have been slowed considerably as a result of the approval of a county-wide referendum blocking the use of property taxes to finance such construction.

Landfills and industrial disposal sites continue to present threats to ground water. The number of land disposal sites, lack of zoning in the past, and lack of controls over substances being dumped have all contributed to serious ground water contamination incidences in the Lexington-Richland County area (see Table 3-3 and Figure 3-3). The Lexington County Landfill, an abandoned sand mine converted to a landfill in 1972, has been the object of much investigation. Nearby is the abandoned City of Cayce dump which appears to be connected hydrologically to the landfill. The highly permeable soils and rapid infiltration have made these two landfills highly suspect as sources of ground water pollution. However, the complexity of the sediments and lack of monitoring have made assessments and definite conclusions difficult. According to the South Carolina Department of Health and Environmental Control (n.d.[a])the shallow aquifer has contained high levels of lead and iron exceeding those of drinking water outside the area; however, contamination of the deeper aquifer has not been confirmed. The department would like to close the landfill. However, evidence of the extent of contamination of the aquifer is not conclusive and, until an alternative site can be located, closing the major county landfill would be difficult.

Hazardous waste sites have also created serious threats to local ground water. Three sites in this area qualify for EPA "Superfund" for clean-up efforts. All three of these sites-Dixiana in Lexington County, Dreyfus Road and Bluff Road in Richland County--were operated by South Carolina Recycling and Disposal which reclaims hazardous and industrial wastes. At the Dixiana site, exposure to weather caused deterioration of some storage drums allowing discharge of toxic and hazardous wastes into the environment. At least two families were advised to close their wells after a preliminary investigation. A more detailed investigation indicated widespread contamination of the shallow aquifer with TDS, ammonia, nitrogen, organic carbon, chromium, copper, iron, lead, selenium, volatile organics, and herbicides. Further monitoring has revealed apparently rapid migration to the deeper parts of the aquifer. DHEC has closed the site, but monitoring

TABLE 3-3: GROUND WATER CONTAMINATION CASES IN LEXINGTON AND RICHLAND COUNTIES, SOUTH CAROLINA UP TO DECEMBER 1982

Type Facility	Major Contaminant(s)	Source(s)	Remarks
Lexington County			
Allied Fibers and Plastic Corporation	Metals, nutrients, TDS, phenols	Unlined lagoons	Ground water investigation conducted as part of facility's overall environmental assessment. Elevated concentrations of metals localized near lagoons. Impact is apparently limited to on-site shallow-water-table aquifer. Monitoring continuing.
Carolina Chemical Co./ Columbia Metropolitan Airport	Pesticide	Landfill	Unpermitted burial of empty pesticide bags resulted in contamination of shallow aquifer by Lindane (43 ug/l) and Toxaphene (570 mg/l. Further study in progress.
Carolina Gravure	Metals	Lagoons, spray irrigation	Ink wastes disposed of via pits in sand with some spray irrigation. Lead as high as 5.6 mg/l, chromium 0.62 mg/l, cadmium 0.781 mg/l. At present, facility cooperating with SCDHEC in study of possible recharge.
Columbia Metropolitan Airport	Aviation fuel (JP-4)	Spills	Fuel storage area spill discovered in surface waters which have now been cleaned up. Five monitoring wells installed by SCDHEC. Indications of prior spills. Appears several spills have occurred in area.
Dutchman Shores Subdivision	Bacteria	Septic tanks, surface runoff	SCDHEC report (February 1981) concluded the widespread occurrence of bacteria in shallow aquifer result of high density of spetic tanks in area and surface runoff.
Frink Street and U.S. 321 gasoline seep	Gasoline	Suspected underground gasoline storage tanks	Gasoline contaminated ground water seeped into excavation. Excavation constructed to repair water lines (possibly affected by gasoline). Suspected source: nearby abandoned underground gasoline tanks.
Leesville	Petroleum	Unknown	New city well could not be used.
Leesville	Organics	Unknown	Eight organics found in 2 public drinking water supply wells. Suspect organics are from degraded petroleum products. Possibly related to previous entry.
Padgett Poultry Farm	Nitrates	Surface infiltration	Abandoned well. Presently using another water-supply source.

(continued)

TABLE 3-3: (Continued)

Type Facility	Major Contaminant(s)	Source(s)	Remarks
Parkwood Subdivision water-table aquifer	Gasoline	Suspected underground gasoline storage tank(s)	SCDHEC investigations have not been able to determine source(s).
Power Oil Company	Gasoline	Underground transmission line	Facility reported loss of 200,000 gallons (suspected) regular grade gasoline leaked from underground transmission lines connecting tank and distribution pumps. Remedial or recovery actions not economically feasible.
South Carolina Recycling and Disposal (Dixana site)	Metals, organics	Surface infiltration, stockpiles	SCDHEC (1981) conducted ground water contamination investigation. The site has been scheduled for clean-up action funded by EPA Superfund.
Springdale private well	Gasoline	Spills	SCDHEC study (August 1980) concluded source to be gasoline station leaking gasoline from aboveground storage tanks. City water now used.
Inland Container Company	Metals	Septic tank/ tile field	Chromium (0.82 mg/l) and lead (0.65 mg/l) detected in 1980. However, 1981 analysis indicates decreasing trend. Potential recharge area for Middendorf aquifer. Septic-tank system receives industrial wastewater containing ink and starch.
Swansea Muncipal Sewage Treatment Plant	Metals	Lagoon	Leaky lagoon in flood plain of small stream. Most of the contaminated ground water discharges to stream. Elevated chromium (1.1 mg/l) and lead (1.38 mg/l). High iron (200 mg/l) and nickel (0.4 mg/l) detected.
Vise Private Well	Fuel oil	Underground home heating oil tank	Kerosene (243 mg/l) found in private well. Suspected source is neighbor's home oil fuel tank.
Wood Brothers Inc.	Acetic acid	Septic tank	SCDHEC study determined odor and iron resulting from rapid movement of food processing waste to water table. Company provided well owner with city water.
Richland County			
Anchor Continental Inc.	Toluene	Underground toluene storage tanks	Discovered as seeps into Gill Creek. Recovery well in place. Extent of problem is unknown.

(continued)

TABLE 3-3: (Continued)

Type Facility	Major Contaminant(s)	Source(s)	Remarks
Ashland Chemical Co.	Acid	Pit	Unpermitted neutralization pit receiving wash-water containing acid. Monitoring well installed near pit exhibited elevated specific conductivity and depressed pit. Further study recommended.
Cardinal Chemical Co.	Organics, tin	Drum storage site	Further study in progress to determine vertical extent of contamination. Facility planning warehouse construction on burial site.
City of Columbia Equipment Services Facility	Gasoline	Transmission line leak	Strong gasoline odor emitted from sewer drains at Hall Institute. Odor traced upstream to stream bank seep, then to facility. Pipe leak discovered and repaired. Recovery actions for gasoline in stream in progress. Evidence indicates multiple spills over extended period of time.
Derrick Private Well	Motor oil, bacteria	Septic tank, automobile garage	Suspected sources upgradient from well are septic-tank/tile-field system and automobile repair garage.
Fairfield Chemical Co.	Organics	Septic-tank/tile-field	Nonpermitted discharge of industrial wastewater into septic-tank/tile-field system cause of problem. Consultants presently studying.
Henry Private Well	Organics	Unknown	Well contains dichloromethane (14.8 ug/l) and tetrachloroethene (4.1 ug/l). Source unknown.
Lindau Chemical Co.	Ammonia, phenols	Lagoons, overland discharge	Geohydrological study completed by SCDHEC in August 1979, concluded shallow ground water contaminated from phenols (up to 912.0 mg/l), ammonia (252.0 mg/l), and chemical oxygen demand (up to 20,000 mg/l). Flashpoint of ground water measured as 140°F. Specific conductivity was 12,000 umhos/cm. Consulting firm investigating. Facility under consent order.
Robbins and Myers, Inc.	Metals	Tile-field	Improper disposal of metal wastewater into tile-field. Further study is planned.
Shell Oil Co. (Gervais and Harden)	Gasoline	Underground storage tanks	Monitoring well detected 5 mg/l oil, grease, and gasoline in ground water at 23.3'. Soil analysis indicated >17,000 mg/kg in soil at depth of 25' below land surface. The study concluded the soil and ground water were contaminated. The gasoline moving along on top of water-table surface.

(continued)

TABLE 3-3: (Continued)

Type Facility	Major Contaminant(s)	Source(s)	Remarks
South Carolina Recycling Disposal (Bluff Road site)	Organics, metals	Waste chemical dump	Preliminary gorund water study completed (1982) by SCDHEC involving 12 wells. Volatile organics appear in all wells. Lateral movement has not been traced. Source is waste chemical storage. Clean-up activities, funded by Superfund are underway. Further study regarding extent and clean-up ground water contamination being developed.
Townsend Textron Sawchain	Metals, nitrate	Land disposal of effluent	Citizens complaint about dead trees lead to discovery of land disposal of metal-plating waste without treatment. Contaminating shallow aquifer with chromium (41.0 mg/l), cadmium (0.5 mg/l), nitrate (74 mg/l), and cyanide (1.05 mg/l). Specific conductivity of ground water as high as 7100 umhos/cm. Consulting firms investigated. Ground water recovery system presently in operation. Site is located in Middendorf recharge zone.
Westinghouse Nuclear Fuel Division	Nitrogen, flouride	Lagoon, spray irrigation	Discovered after a fish kill below a spring. First phase studied by company with 33 wells has been completed. Further study is planned by the company. Ammonia as high as 909 mg/l, flouride up to 125 mg/l.

Source: South Carolina Department of Health and Environmental Control, Ground Water Protection Division 1983, 91-96.

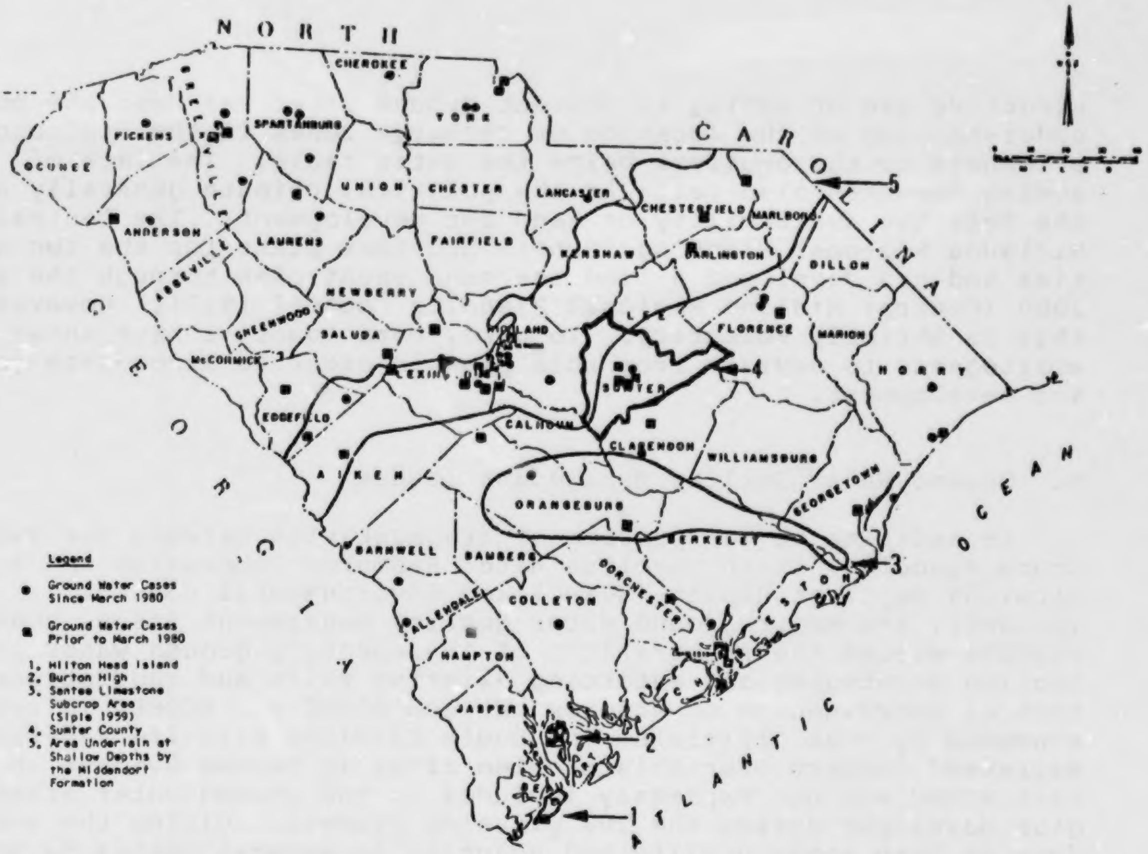


Figure 3-3: Density map of ground water contamination cases in South Carolina.

Source: South Carolina Department of Health and Environmental Control 1983.

will be continued to determine the extent of future contamination (South Carolina Dept. of Health and Environmental Control 1982).

The Bluff Road site involved leaks and spills directly onto the ground which is composed primarily of sands and gravels mixed with some clay. Although in use by SCR&D only since 1976, soil samples in 1980 revealed high levels of metals and various organic compounds. One nearby well was found to be contaminated with Dieldrin. Later ground water analysis indicated widespread contamination from volatile organic compounds (trichlorofluoromethane, methyl benzene, ethyl benzene), iron, lead, manganese, and odor (South Carolina Dept. of Health and Environmental Control 1982).

Land use controls in both counties have been negligible until recently. Since both counties are a mix of urban, agricultural, and industrial development, the potential for future threats to ground water quality are considerable. A major constraint to effective use of zoning to protect ground water has been the poor understanding of the location of recharge zones in the Piedmont and elsewhere to the aquifers below the water table. The lack of zoning measures also reflects the political climate generally and the relative availability of land for development. The Central Midlands Regional Planning Council provides plans for the two counties and has developed a land use management plan through the year 2000 (Central Midland Regional Planning Council 1977). However, this is strictly voluntary. To date, both counties have shown a willingness to deviate from this plan in order to accomodate growth and development.

D. Ground Water Quality Management Issues

In addition to the problem of fragmentation between the two state agencies, South Carolina Water Resource Commission and South Carolina Dept. of Health (SCWRC) and Environmental Control (SCDHEC), the major ground water quality management issues seem to revolve around the frustrations of implementing ground water protection strategies and enforcing existing rules and regulations. Lack of coordination of efforts between SCWRC and SCDHEC is readily conceded by most officials. The South Carolina Wildlife Federation expressed concern over this problem after it became evident to them that SCWRC was not expressly included in the ground water strategies developed during the 208 planning process. Citing the work done on both water quality and quantity in several basins by SCWRC, the federation suggested better coordination of research and planning efforts (South Carolina Wildlife Federation 1981).

SCDHEC officials in charge of implementation of federal and state water quality programs must operate within the political context of federal-state-local relations. Some officials must, at times, operate on a short-term or crisis management basis primarily because of the inadequate information on ground water throughout the state. Moreover, they need to work cooperatively with local officials who are concerned about water quality especially as it relates to drinking water and economic development opportunities. The burden of proof that a serious problem exists falls on the state agency. If such a problem is found to exist, it often crosscuts local governmental authorities such as county lines, towns and cities, etc., thus requiring orchestration of cleanup efforts. As a regulatory agency, SCDHEC typically receives a considerable amount of criticism regardless of its position on a particular issue because of the local interests involved. Having to close a landfill or a domestic well because of contamination causes inconvenience and expense and, at times, raises difficult questions about the responsibility for protection and cleanup.

Recently, the state has enacted legislation designed to improve the management of water quality, including a requirement to license well drillers. Prior to this, any one could legally drill water wells in the state, thus exposing domestic wells to potential contamination and a short well-life due to improper well construction and drilling practices. Abandoned wells, though required to be sealed, are also considered to be potential sources of contamination and are difficult to manage due to lack of information and staff.

South Carolina has never permitted underground injection of wastes through wells. Therefore, the state does not have the current problems that other states have with potentially polluting sites. However, state officials are considering banning these in the state rather than beginning a potentially troublesome program which would be very costly for the state to implement.

E. Ground Water Information Systems

Compared to the coastal areas of South Carolina, very little work has been done on the characteristics of ground water in this two-county inland area. The U.S. Geological Survey (USGS) has only about three or four monitoring wells in the entire Piedmont area and much of the information about the local ground water has been gleaned from private well drillers and industry records (USGS, South Carolina Division 1982). Samples of ground water quality have not been taken over a sufficiently long enough time period to understand just what characteristics are natural, how the water is changing, etc.

The recent passage of the South Carolina Water Use Reporting and Coordination Act of 1982 is the beginning of a state effort to develop a comprehensive data base on water resources in the state in order to improve management options in times of emergency. Although ground water quality is not a primary focus of the legislation, the SCWRC has included some water quality descriptions in its assessments of availability. The SCWRC estimates that about 95 percent of all users are covered under this legislation.

The SCDHEC has an extensive monitoring effort based in its district offices. However, sophisticated chemical analysis is not routinely performed (about once every three years) and many individual drinking supplies are tested only upon the request of the owner. Developing a more complete ground water information system will require a better understanding of ground water movement, recharge areas, aquifer structure, etc., than currently exists in parts of South Carolina.

3.3 GEORGETOWN TO WILMINGTON CASE STUDY DESCRIPTION

3.3.1 Status and Trends

The Georgetown-Wilmington case study area is a four-county area bordering the Atlantic Coast: Georgetown and Horry counties in South Carolina and Brunswick and New Hanover counties in North Carolina (Figure 3-4). The counties have experienced continued growth and dramatic seasonal influxes of tourists. This growth and development have placed a stress on the area's ground water resources. Management programs have been developed or are being considered by local and state governments for dealing with both supply and quality problems. The area provides examples of a range of ground water supply and quality problems, issues, and policy opportunities. Because the area is representative of coastal areas highly dependent on ground water, it was selected as case study site.

A. Population and Economics

The 3,044 square mile multicounty area (about two-thirds the size of Connecticut) has a permanent population of 282,008 according to the 1980 census (Table 3-4). This represents a growth of 34 percent during the previous decade, substantially above the 22 percent growth average for the Southeast region, and 11 percent for the nation. Although much of the population is located in the seven largest cities, the outlying areas have attracted the rapid growth during the past decade. Wilmington, the largest city, actually declined from 46,169 in 1970 to 43,779 in 1980, for example. Wilmington, supplied by surface water, has not experienced a major increase in water demand. On the other hand, the outlying townships rely on ground water and have grown between 50 and 60 percent during the past decade (Wilmington-New Hanover Planning Department 1980).

The permanent residents are only representative of water demands in towns with a relatively stable population such as Wilmington, Georgetown, and Conway. In the Myrtle Beach area alone, the seasonal population swells the ranks from about 50,000 (including the other coastal tourism towns in Georgetown and Horry counties) to more than 350,000 during the summer. This seasonal population also occurs in Brunswick and New Hanover counties. Importantly, the seasonal population occupies the coastal towns that rely exclusively on ground water.

Along with the major influx of tourism to the area, manufacturing has also increased in recent years to become the major source of both income and employment. Tourism ranks second, followed by wholesale trade, and services. About 27 percent of the nonagricultural employment (Table 3-5) is in manufacturing, primarily in apparel and textiles as well as metals, paper and chemicals. Wholesale and retail trade represents 23 percent of employment.

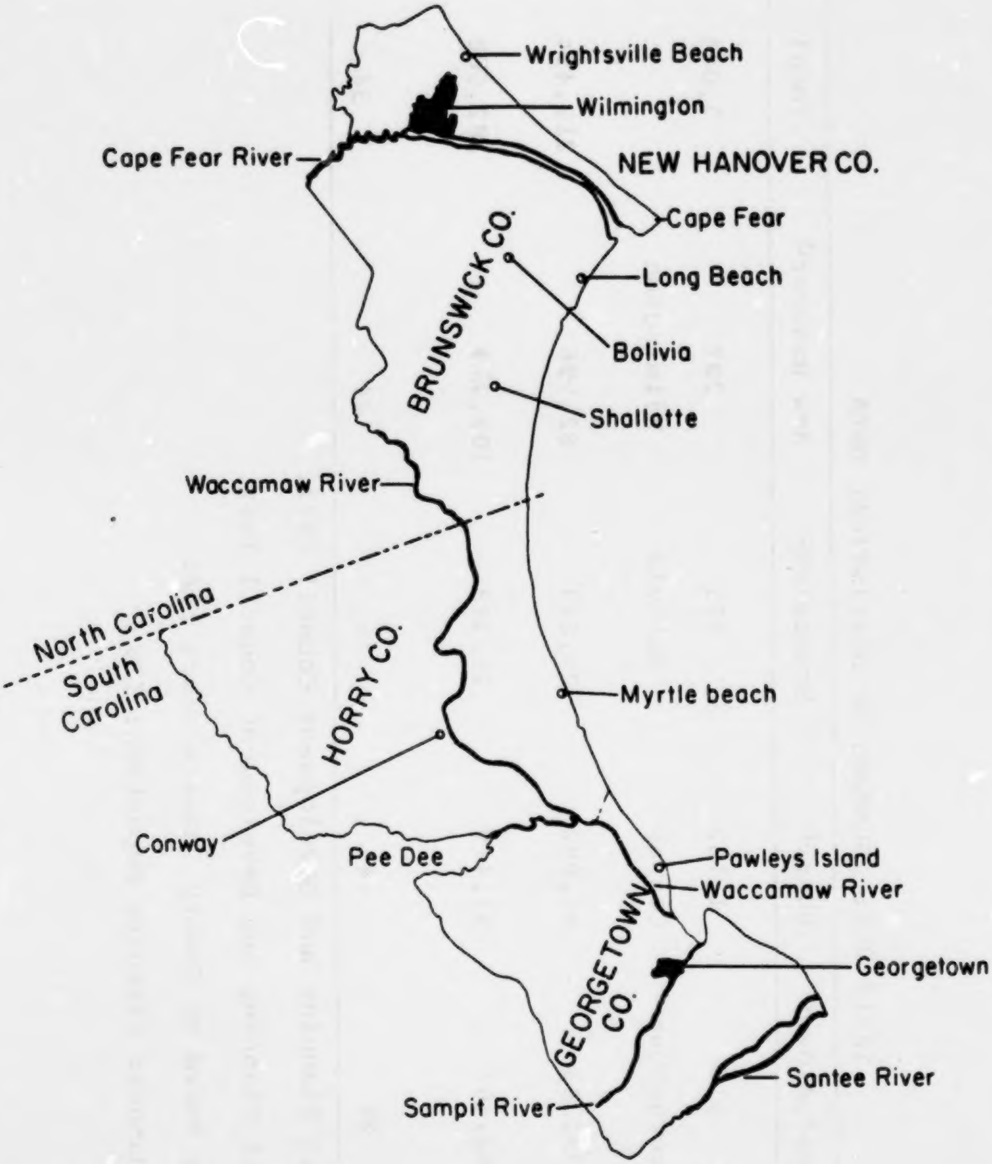


Figure 3-4: Georgetown to Wilmington case study area.

TABLE 3-4: SUMMARY OF STATISTICAL DATA

	Georgetown[a]	Horry[b]	Brunswick[c]	New Hanover[d]	Total
Area (square miles)	812	1,152	873	207	3,044
County Seat	Georgetown	Conway	Bolivia	Wilmington	
Population (1970)	33,243	69,992	24,223	82,996	210,454
Population (1980)	42,461	101,419	35,349	102,779	282,008
Ten Year Growth Rate (Percentage)	28	44	46	24	34

[a] Waccamaw Regional Planning and Development Council 1977.

[b] Waccamaw Regional Planning and Development Council 1981.

[c] Brunswick County Board of County Commissioners 1981.

[d] Wilmington-New Hanover Planning Department 1980.

TABLE 3-5: EMPLOYMENT CHARACTERISTICS

Location	Total	Manufacturing	Construction	Transportation & Public Utilities	Wholesale & Retail Trade	Finance, Insurance & Real Estate	Services & Mining	Government
Georgetown[a]	13,620	4,690	820	360	2,670	470	2,010	2,580
Horry[a]	37,490	7,170	2,380	1,220	10,420	1,710	8,420	6,120
Brunswick[b]	13,780	6,580	3,900	340	1,000	250	360	1,350
Wilmington[c]	41,780	9,880	2,130	3,640	10,240	1,640	6,040	8,110
Total	103,900	28,320	9,240	5,560	24,330	4,070	18,160	22,380
Percentage	27.3	8.9	5.4	23.4	16.2	17.5	16.2	17.5

[a] South Carolina Budget and Control Board. 1981. South Carolina Statistical Abstract. Columbia, S. C.: South Carolina Division of Research. (Data for 1980.)

[b] Brunswick County Resources Development Commission. 1981. Brunswick County, North Carolina, Coastal Area Mangement Act Land Use Plan Update. Bolivia, N.C.: N.p. (Data for 1974.)

[c] Wilmington-New Hanover Planning Department. 1980. Population and Economic Growth and Future Land Use Needs 1980-1990. Technical Report No. 7. Wilmington, N. C.: Wilmington-New Hanover Comprehensive Planning Program. (Data for 1978.)

Most of the tourism economic activitiy is reflected as employment in the trade and services industries, as well as government. Projections made by county planning agencies for the 1980-1990 decade indicate that population growth may continue, ranging from 33.3 to 42.5 percent, or a total projected population of about 375,000 to 402,000 by 1990. BEA projections also indicate that substantial increases (although at more conservative rates) may continue through the year 2030. According to county and regional plans, much of this growth may occur along the coastal areas.

Nonresident (visitor) population growth is also projected to continue. The total seasonal population in Horry County, for example, is projected to increase from an estimated 300,000 (Myrtle Beach Chamber of Commerce 1981) in 1980 to 460,000 by 1990 and 540,000 by 1995 (Wacamaw Regional Planning Development Council 1976).

Employment growth is projected to increase in most sectors. However, in New Hanover and Brunswick counties the largest growth rate is projected for service employment, which is projected to surpass manufacturing employment by 2030 (U.S. Dept. of Commerce, Bureau of Economic Analysis 1981). Some of the past growth industries are water intensive, such as paper mills and petrochemicals. The service related industries, such as resorts and golf courses also can be water intensive and in some respects yield high pollution loads. Although golf courses in South Carolina have been managed in many instances to assimilate wastewater from resort complexes, this practice is prohibited in North Carolina.

B. Water Resources and Supply Systems

The area is drained by an extensive natural and man-made system of streams and canals. Extensive areas of brackish surface water occur in tidal marshlands along the coast and extend about 20 miles upstream in the larger rivers. Ground water resources are present in the five aquifers: Water Table, Tertiary Limestone, Pee Dee, Black Creek, and Tuscaloosa (Table 3-6). The bedrock below the Tuscaloosa Aquifer (or Middendorf) is basically impermeable. Figure 3-5 provides a diagramatic representation of the aquifers in a section that is approximately representative of the North Carolina-South Carolina Border.

The thick Black Creek Aquifer supplies nearly all the municipal and industrial water used in Horry and Georgetown counties. The Pee Dee and Tuscaloosa (Middendorf) are of poor quality and are not used as municipal supplies in this study area. To the north, in Brunswick and New Hanover counties, the Tertiary Aquifer comes onshore and forms the most important aquifer even though it is relatively thin and found at less than 200 feet deep. In contrast to most of Horry and all Georgetown County, the Black Creek is too saline for use in Brunswick and New Hanover counties. Thus, the

TABLE 3-6: MAJOR AQUIFERS[a]

	CHARACTERISTICS
Water Table	This aquifer consists of 20 to 80 feet of sand. Water from this aquifer supplies industry in northwestern New Hanover county, and elsewhere; is sometimes used for domestic or irrigation supplies.
Tertiary Limestone[b, c]	In Brunswick and New Hanover Counties the aquifer contains 10 to 130 feet of permeable limestone and sandstone. Where it most permeable, yields of up to 1,000 gallons per minute can be obtained. The unit yields a hard, calcium, bicarbonate type water, and may have a high iron content. All the communities in Brunswick County except Ocean Isle Beach, and all communities except Wilmington and the industry in northwestern New Hanover County use this aquifer.
Pee Dee	The Pee Dee Aquifer lies directly beneath either the Water Table Aquifer or the Tertiary Limestone Aquifer. It consists of approximately 500 feet of interlayed sands, silts, and clays. In Horry County this water is of poor quality with high concentrations of iron and sulfates and in New Hanover and Brunswick County it is brackish.
Black Creek	This aquifer lies directly beneath the Pee Dee Aquifer. The water from the aquifer is used widely in the Horry County area. The water is generally of good quality except for the fluoride and sodium content. However, in northern Horry County, Brunswick and New Hanover County the water is brackish.
Tuscaloosa (Middendorf)	This aquifer lies below the Black Creek Aquifer and consists of approximately 150 to 250 feet of interbedded sand, silts, and clays. It has a very high chloride content and has not been considered for supplying potable water.

Source: Department of Natural Resources and Community Development 1982.

[a] Waccamaw Regional Planning and Development Council 1977.

[b] Robison and Mann 1977.

[c] Narkunas 1980.

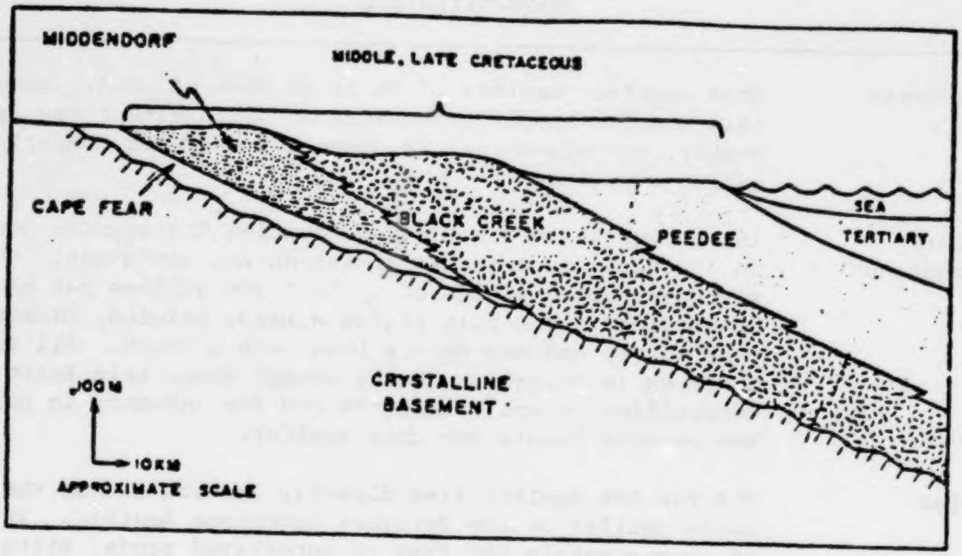


Figure 3-5: Diagrammatic representation of the major aquifers in the study area. The Tertiary (Limestone) formation is onshore in Brunswick and New Hanover counties.

Source: Modified from Swift and Heron 1969.

aquifer systems used in the study area are divided almost at the South Carolina-North Carolina Border.

Surface water and ground water provide vastly different proportions of total water supply among the counties of the study area, primarily the result of city government and industry development decisions. In Horry County for example, ground water provides the sole source of supply to the many municipalities. As indicated above, in both Horry and Georgetown counties all these supplies come from the Black Creek Aquifer (Figure 3-6). The result of this use is a major reduction in the water surface in the Black Creek formation, which is depressed more than 50 feet in some locations (compared to a reference well). The cone of depression actually extends well into Brunswick County, where water levels of monitoring wells are dropping about one to four feet per year in parts of the Black Creek Aquifer (North Carolina Dept. of Natural Resources and Community Development 1982). Some of the wells along

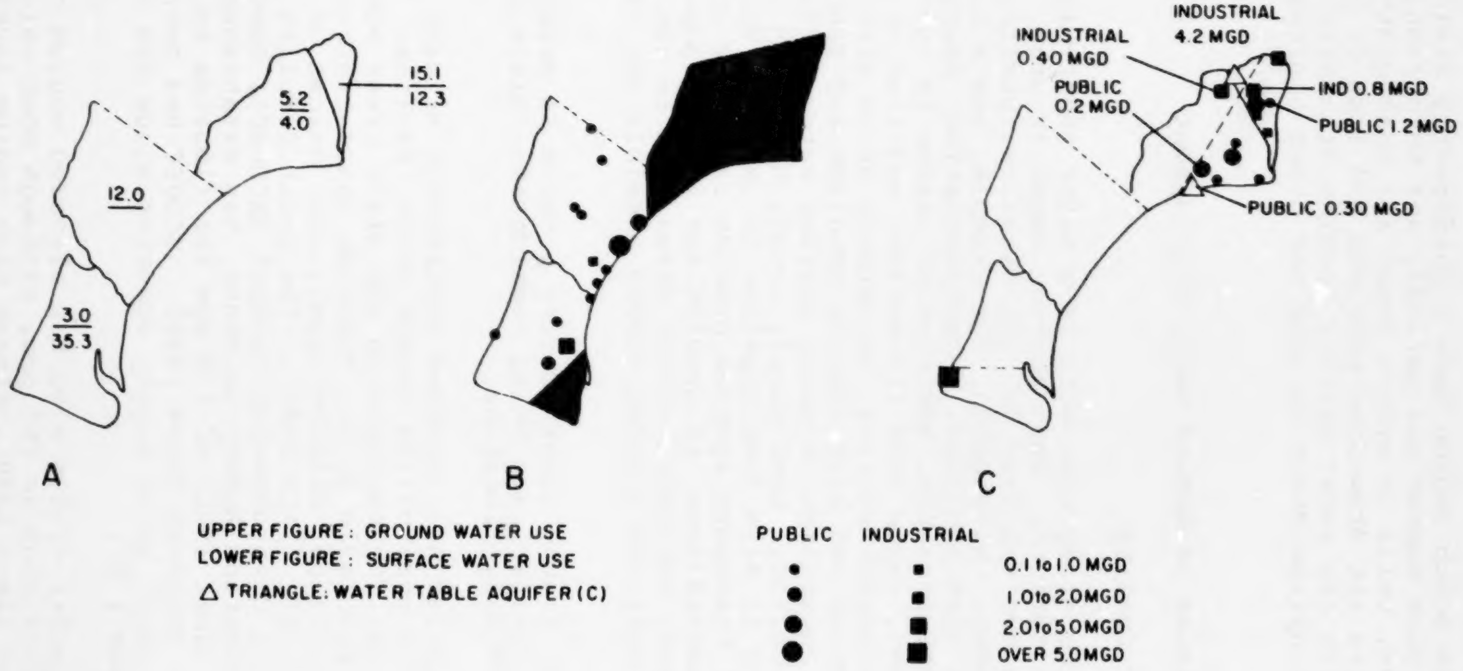


Figure 3-6: Water Use Patterns.

A. Surface and ground water use (Million gallons/day).

B. Cretaceous Aquifer use

C. Tertiary Limestone Aquifer use.

Shaded areas in Figure B indicates all or most of aquifers contain in excess of 1,000 mg/liter total dissolved solids.

Source: Coastal Plains Regional Commission 1979.

the coast in the Myrtle Beach region have significantly diminished production during the peak summer use periods, and this leads to shortages. In addition, wells in Myrtle Beach are inadequately spaced which intensifies the draw-down problems and loss of pumping capacity. Combined with the water quality problem discussed later, this shortfall has led Myrtle Beach to look for other sources of supply.

3.3.2 Problems and Issues in Ground Water Development

A. Poor Ambient Water Quality

Water quality in the study area acts as a major constraint in selecting water supply options. When surface water is used, costly water treatment plants are required for chlorination, particulate removal and pH adjustment. Wilmington, for example, has a raw water treatment system that includes: prechlorination, coagulation with alum and lime, sedimentation, addition of carbon to control taste and odor as needed, rapid sand filtration, addition of phosphate compounds for corrosion control, adjustment of pH with caustic soda, postchlorination and fluoridation (Robison and Mann 1977). Another major constraint on using surface water is salinity in the near-coastal location. Long supply canals have been used for Georgetown, and the 21 mile long pipeline is used for Wilmington. This fresh water transport systems provide raw water at considerable expense. Nevertheless, to provide for further population and industrial expansion, the major growth areas such as the Myrtle Beach and Brunswick County are looking toward possible use of surface supplies.

The type of ambient ground water quality problem is dependent on which of the three aquifers are being considered: Black Creek, Water Table, or the Tertiary Limestone.

The Black Creek Aquifer has isolated occurrences of salt water, and it becomes generally more saline toward North Carolina. However, the major water quality concerns in the Black Creek are fluorides and sodium (see Table 3-7). Fluoride concentrations range as high as 5.5 parts per million (ppm), with values of about 4.0 ppm occuring frequently (Zack 1980). The South Carolina Department of Health and Environmental Control (SCDHEC), based on U.S. Environmental Protection Agency guidance, has estabished a maximum concentration limit (MCL) of 1.6 ppm for flouride to prevent tooth mottling in children (Zack 1980). SCDHEC has been issuing exemptions to local water supply agencies since the MCL went into effect in June 1977.

The Black Creek Aquifer system also has elevated sodium concentrations that range as high in 700 ppm, although most values are between 200 and 500 ppm (Zack 1980). These high sodium levels have raised public health concerns as potentially contributing to

TABLE 3-7: WATER QUALITY IN SELECTED WELLS (mg/l)

Parameter	Georgetown[a] County (Black Creek)	Horry[b] County (Black Creek)	Brunswick[c] County (Tertiary Limestone)	New Hanover[d] County (Tertiary Limestone)	Brunswick/ New Hanover[e] (Mainland) (Tertiary Limestone)
Iron	0.1	0.2	2.7	0.1	0.01-5.0
Calcium	2.2	3.4	100.0	50.0	4.00-8.00
Sodium	270.0	3.4	82.0	120.0	5.0-25.0
Chloride	35.0	124.0	130.0	160.0	10.0-60.0
Fluoride	3.5	4.3	0.2	0.4	--
Dissolved Solids	678.0	786.0	518.0	499.0	150-300
pH (pH units)	8.3	8.1	7.3	7.4	--

[a] Data for a well at Pawley's Island. Zack 1980.

[b] Data for a well at Myrtle Beach. Zack 1980.

[c] Data for a well at Long Beach. Robison and Mann 1977.

[d] Data for combined sample of six wells from Wrightsville Beach. Robison and Mann 1977.

[e] North Carolina NRCO. 1983. Personal communication.

coronary disease, although detailed evaluations of the sodium risk are not available (U.S. Geological Survey 1982). There is an apparent elevated level of coronary and circulatory disease in the Myrtle Beach vicinity, but the cause of this is not determined and may be related to other factors, such as the prevalence of retirees in the population (U.S. Geological Survey 1982). Nevertheless, the elevated sodium levels are viewed as a problem, especially by those who wish to restrict their sodium intake.[1]

---

[1] Additional problems with the ground water quality in Georgetown and Horry Counties are high levels of chloride and dissolved solids; often the latter two consitute more of a problem in the Pee Dee Aquifer, just above the Black Creek. Iron, turbidity, and hydrogen sulfide are also aesthetic water quality problems by discoloring water and introducing odor (Spigner, Stevens and Moser 1977).

In Brunswick and New Hanover counties the ground water from the Tertiary Limestone is hard, has moderate dissolved solids concentration and may contain excessive amounts of iron or hydrogen sulfide. At some beach locations the dissolved solids concentration and chloride concentration are considered high (Robison and Mann 1977) although no apparent health concerns have been raised concerning the quality of the Tertiary Limestone Aquifer. However, local pollution of the Water Table Aquifer has raised public health concerns (see Section 3.3.2-C below). A summary of selected chemicals posing water quality problems is presented in Table 3-8.

B. Overview of Ground Water Contamination

Table 3-9 lists some selected ground water contamination cases for the two counties in North Carolina, while Table 3-10 list documented cases for the two South Carolina counties. These tables indicate the wide variety of causes of ground water pollution--wastewater lagoons, leaking storage tanks, septic tanks, land disposal of wastewaters, injection wells, leaky pipelines, and landfills.

C. Point Source Pollution Problems

Most counties of the case study have municipalities with a sewage treatment system, such as in Horry and Georgetown counties. These sewer systems have point source discharges to swamps, receiving streams, or the Atlantic Ocean. All the municipalities in New Hanover County, for example, have sewage treatment and point source discharges. In Brunswick County, however, only two communities have point source wastewater discharges. Residents of almost the entire county use septic tanks (Brunswick County Board of Commissioners 1981).

The sewage discharges to streams in the coastal zone have been identified as important water quality problems. Elevated coliform counts have contributed to the closing of all the region's shell fish beds.[1] The discharges to the Intercoastal Waterway in Horry County may present problems for the City of Myrtle Beach as it develops plans to derive its water supply from the polluted waterway.

Industrial and storm sewers in the Myrtle Beach area also are affecting water quality. The coliform levels in many of Myrtle Beach's storm sewer outfalls far exceed standards for wastewater discharges (Moore, Gardner and Associates 1979). Because many of

---

[1] Nonpoint source pollution from septic tanks has apparently also contributed to this problem (Brunswick County Board of Commissioners 1981).

TABLE 3-8: SELECTED GROUND WATER QUALITY PROBLEMS IN THE GEORGETOWN TO WILMINGTON STUDY AREA

Quality Problems (Source)	Location	Characteristics
Sodium (natural)	Beach Creek formation, Horry County, Georgetown County	Potential health concern, especially to elderly or those with circulatory disease
Flouride (natural)	Black Creek formation, Horry County, Georgetown County	High levels of tooth mottling in children (Zack 1980)
Bacterial (Contamination)	Water table throughout study area, especially New Hanover County	Increased risk of hepatitis, meningitis, and other disease (Eakins 1981)
Iron (natural)	Occasionally throughout study area but especially Brunswick and New Hanover Counties	Nuisance deposits in plumbing, stains clothes
Dissolved Solids (natural)	Horry County, Brunswick County, New Hanover County	Contributing to scum deposits
Hardness (natural)	Brunswick and New Hanover County (tertiary limestone formation)	Causes surface deposits, reduces surfactant capacity
Salt Water (Intrusion)	Northern Horry County Ocean Isle Beach	Reduces potability of water supply

TABLE 3-9: SELECTED GROUND WATER CONTAMINATION CASES IN BRUNSWICK AND NEW HANOVER COUNTIES, NORTH CAROLINA (1982 through present)

Type Facility	Major Contaminant(s)	Source(s)	Remarks
Brunswick County			
U.S. Government	Inorganic (chlorides)	Lagoon (400 ac.)	Lagoon contains dredged spoil material. Brackish water from there has contaminated the Water Table and Tertiary Limestone aquifers. Flora in some downgradient fresh-water ponds have been adversely impacted. Some remedial measures may be attempted during 1983.
Chemical Industry	Inorganic (sulfates)	Landfarm (1100 ac.)	Monitoring data indicates Water Table aquifer contaminated by mycelim waste spread on land surface. Sulfate is the primary contaminate.
Chemical Industry	Inorganic, organic	Spray field (26 ac.)	Monitoring data indicates Water Table aquifer contaminated with dissolved solids and organics (mostly ammonia and organic nitrogen).
Gasoline Filling Station	Petroleum	Leaky storage tank	Field investigation revealed that seven domestic wells (all exposed to the Water Table portion of Tertiary Limestone aquifer) were adversely impacted by gasoline spill.
Nuclear Power Plant	Inorganic (chlorides)	Unlined canals (8 miles)	Monitoring data indicates Tertiary Limestone aquifer has been contaminated with brackish water. No monitor wells have been constructed in the Water Table aquifer.
Restaurant	Bacteria	Conventional septic tank, nitrification field (1/4 acre)	Total and fecal coliform detected in monitor well located downgradient from nitrification field. Monitor well exposed to water table well.
New Hanover County			
Chemical Industry	Leaky transmission line	Metals	Substantial quantities of chromium chemicals leaked into the Water Table and Tertiary Limestone aquifer. Three on-site industrial wells were contaminated with chromium. Since 1975 remedial actions have removed about 75 percent of the spilled chemicals.

(continued)

TABLE 3-9: Continued

Type Facility	Major Contaminant(s)	Source(s)	Remarks
Chemical and Manufacturing Industry	Nitrates	Lagoon (2 ac.)	Monitoring data indicate that nitrates from lagoon have entered the Water Table aquifer. Nitrate concentration in downgradient wells vary. But nitrate (as nitrogen) concentrations above drinking water standards are common.
Chemical Industry	Organic acids	Injection wells	Organic wastewater was injected into the Tuscaloosa aquifer (brackish) from 1968 to 1972. In 1971 the injected wastewater leaked from the Tuscaloosa to the Black Creek aquifer (also brackish). Because the wastewater could not be isolated in the Tuscaloosa aquifer the practice was discontinued.
Chemical Industry	Nitrates	Spray field (60 ac.)	Monitoring data indicate that the Water Table aquifer has been contaminated by treated wastewater effluent that is sprayed on the field. Nitrates are the primary contaminant of concern: concentrations in several wells exceed drinking water standards.
Residence	Bacterial	Conventional septic tank, nitrification line	Residential well was contaminated by bacteria from septic tank effluent. Well depth was 30 feet.
County	Organic, Inorganic, Metals	Landfill (72 ac.)	Landfill contaminated Water Table aquifer. Seven domestic wells contaminated before community connected to a community water system. Contamination problem discovered in 1979.
Chemical Industry	Nitrates	Multiple	Water Table aquifer contaminated by air pollution particulate matter, slops and spills, and wastewater from lagoon. Three on-site industrial wells contaminated with nitrates (concentrations exceeded drinking water standards).
Conventional Power Plant	Inorganic (chlorides)	Lagoon (1100 ac.)	Data indicate slightly brackish water from lagoons has contaminated Water Table aquifer. Several industrial wells were adversely impacted by source.
Oil Storage Facility	Petroleum	Leaky bulk storage tank	An estimated 260,000 gallons of number 2 fuel oil leaked onto the water table from a hole in the bottom of the bulk storage tank. Six months after remedial efforts were initiated 195,000 gallons of the spilled oil were recovered.

(continued)

TABLE 3-9: Continued

Type Facility	Major Contaminant(s)	Source(s)	Remarks
Chemical Storage Facility	Organic	Leaky transmission line	An estimated 270,000 gallons of paraxtlene leaked onto the water table from a hole in a pressurized transmission line. Since 1981, 237,000 gallons of the spilled product has been recovered. This product entered sewer collection lines.
Chemical Industry	Organic (methanol)	Leaky bulk storage tank	An unknown quantity of methanol entered the Water Table aquifer from a hole in the bottom of the tank: 495,000 gallons of this spilled product was recovered before remedial operations were discontinued.

Source: North Carolina Dept. of Natural Resources and Community Development 1983.

TABLE 3-10: SELECTED GROUND WATER CONTAMINATION CASES IN GEORGETOWN AND HORRY COUNTIES, SOUTH CAROLINA (1982 through present)

Type Facility	Major Contaminant(s)	Source(s)	Remarks
Georgetown County			
Steel and Ferreduction	Metals, nutrients	Landfill/ abandoned dump	SCDHEC study (1980) detected elevated levels of metals and nutrients. Further studies by company. Worst source has been capped with clay. Underlain by old county dump.
Laundromat	MBAS	Spray irrigation	Four monitoring wells sampled 3 times in 1 year at this spray irrigation facility. MBAS detected in each, as high as 38 mg/l (SCDHEC study, 1980). Site conditions include very permeable surficial sands, and shallow water table.
Private well	Saltwater	Dredge spoil	Salty dredge spoil placed in abandoned coquina mine. SCDHEC wells indicating high conductivity were used to determine extent of plume.
Horry County			
AVX Corporation	Chromium, TOC	Sludge disposal	Previous facility owner, American Gear and Pinion, disposed metal-bearing sludge into ditch and then covered. Present owner investigating possibility of vertical migration of contaminants.
Shopping Center	TDS, MBAS	Lagoon	Nine SCDHEC monitoring wells around this unlined, aerated, oxidation lagoon for domestic wastewater. Besides contaminants listed, elevated concentrations of nutrients were detected 40 meters from lagoon. Site conditions include very permeable surficial sands and high water table.
Manufacturing	Metals	Disposal area	Improper disposal of listed hazardous waste led to ground-water contamination by mercury and barium. Further study in progress by company.
Air Force Base	Jet fuel (JP-4)	Spill	120,000 gallons spilled. French-drain recovery system installed immediately after spill in January 1980. 75-100 gallons/day recovered. Further recovery planned.

(continued)

TABLE 3-10: Continued

Type Facility	Major Contaminant(s)	Source(s)	Remarks
Estates	Ammonia	Holding ponds	Elevated ammonia concentrations (over background) indicate contamination of confined shallow aquifer.
Convenience Store	Gasoline	Underground storage tanks	Gasoline found in manhole in October 1981. SCDHEC investigated, installed monitoring wells and advised appropriate personnel regarding safety hazards due to presence of explosive levels of gasoline vapors in manhole and in recovery trench. Clean-up actions ae not presently required. Flash fire occurred recently (November 1982) due to explosive gasoline vapors.
Trailer Park	Nitrate	Septic tanks	Two wells in area of small, concentrated tile fields. Three to four trailers share a single septic tank/tile field, which receives poor effluent rennovation from permeable sediments and high water table. Concentrations as high as 26 mg/l detected in 1980.
Private Well	Organics	Improper storage of chemicals near well, poor well construction	Lasso (1.73 mg/l), Carbofurna (4.0 ug/l), Carboryl (0.36 ug/l).

Source: South Carolina Dept. of Health and Environmental Control, Ground Water Protection Division 1983.

the outfalls empty onto the city's beaches, a public health threat exists (Moore, Gardner and Associates 1979). An additional problem is broken or leaky underground tanks and pipelines. Probably the largest source of complaints from owners of shallow wells in the south coastal area of North Carolina (e.g., in New Hanover County) is gasoline contamination of well water (North Carolina Dept. of Natural Resources and Community Development 1982).

D. Septic Tank Pollution

The problem of excessive or malfunctioning septic tank systems is not just a local problem within the coastal area but is a regionwide problem where poor soils exists. In Brunswick County, as an example, 54.6 percent of total land acreage has been judged to be unsuitable for conventional spectic tank systems (Brunswick County Board of Commissioners 1981). Almost all farms, homes, institutions, and commercial facilities in Brunswick County have a conventional septic tank and filter field system. Here the availability of large acreage and the absence (except for two municipalities) of public sewers renders the septic tank system the most economical method for sewage disposal (and is generally an improvement of amenities over the pit privy). Problem areas are aggravated when septic tanks are constructed in emerging urban or suburban areas with small lot sizes, with either too porous or impermeable soils and with seasonally high water tables.

Much of Georgetown, Horry, and New Hanover counties also have poor soils for septic tanks: soils either drain too fast (so that water table contamination can occur) or they drain too slow (so that sewage seeps to the surface) (Waccamaw Regional Planning and Development Commission 1977; Eakins et al. 1981). As a result, improperly treated sewage can be injected into shallow ground waters or effluent seeps to the surface at some time during the year to be washed into nearby surface waters by subsequent rains. Despite poor soils, in some areas of New Hanover County, for example, 383 septic tanks occur within a one-half square mile area, resulting in coliform counts in adjacent waters 40 to 60 times higher than surrounding communities (Eakins et al. 1981).

E. Solid Waste Disposal

Landfill sites are also a major problem potentially affecting ground water quality. Horry County, for example, has only one approved site for municipal solid waste. This site is essentially full (Waccamaw Regional Planning and Development Council 1982) and new space is difficult to find.

The operation of a landfill which began in 1973 in the Flemington area of New Hanover County provides a prominent example of ground water pollution problems. Flemington area residents have been concerned since 1973 that leachate from the county's only landfill would contaminate their drinking water supplies. The presence of leachate detected in monitor wells located within the landfill property, poor water quality in some of the private wells near the landfill and consideration for expansion of the landfill led the North Carolina Division of Environmental Management to make a ground water study in the area in 1978 (North Carolina, Dept. of Natural Resources and Community Development 1978).

The 1978 state study did not have evidence of chemical concentrations in water wells in excess of limits established by the National Interim Primary Drinking Water Standards; however, landfill leachate has caused the water in some privately owned wells to be offensive and distasteful because of high concentrations of iron, manganese, and other constituents. EPA studies later indicated vinyl chloride and other toxic substances were present in the ground water and a suit was filed by the U.S. Justice Department in June 1980 against New Hanover County; this suit also involves the State of North Carolina (Allis 1980). The privately owned wells which appear to be impacted by the landfill (see Figure 3-7) obtain water from the aquifer at depths of 10 to 35 feet below mean sea level. Ground water contamination appears likely to continue for several decades, although the extent of further leaching from the landfill is unknown (North Carolina Dept. of Natural Resources and Community Development 1978).

The Flemington landfill was closed in 1979 and other temporary sites were used. During a short period of time, waste was trucked 120 miles to Raleigh, prior to the completion of a new landfill in the northern portion of New Hanover County. This new landfill is designed generally according to hazardous waste disposal criteria, with double synthetic liners and a wastewater treatment from the landfill drainage system. Although constructed at considerable expense to the residents of New Hanover County, they now apparently have a relatively secure solid waste disposal site.

F. Fragmented Growth and Water Supply Management

The four county region has strong economic pressures to develop water supplies that satisfy industrial, commercial, and residential growth. Local governments have sought funds to expand services to minimize growth constraints that include: (1) a rural road system that is inadequate; (2) poorly drained soils that create difficulties for septic tank use; and (3) water supplies that are of poor quality or inadequate to support the longer term growth. The road system is improving (but will likely remain a perpetual problem). Water and sewer authorities have been actively implementing projects to respond to the latter two constraints.

Three value conflicts are key to understanding these growth constraints and the resultant management problems: (1) local water

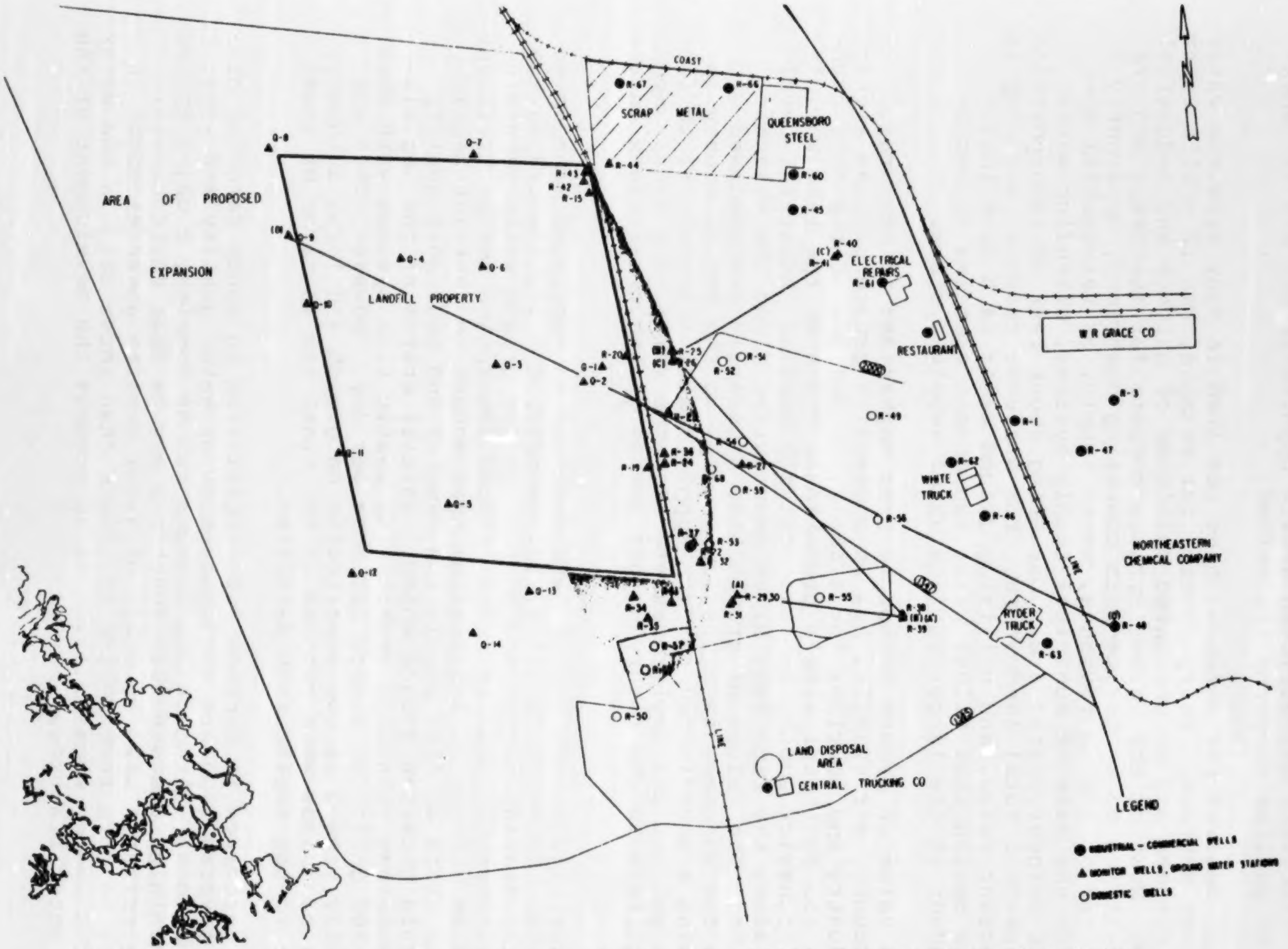


Figure 3-7: Area outside Flemington landfill impacted by leachate.

Source: North Carolina Dept. of Natural Resources and Community Development 1978.

supply authorities desire autonomy; (2) local developers apparently desire relatively unrestricted growth opportunities; and (3) environmental quality concerns are valued.

Local desires for autonomy have resulted in many separate water management systems. Horry County, for example, has 12 public water supply systems and an uncounted multitude of private and industrial systems. Most of the larger systems compete for customers and are also unwilling to cooperate with competing districts, apparently out of fear of losing revenues, water supply, or territorial control. In the case of municipal supply systems, extending water mains to unincorporated areas may bring about fear of incorporation to independent rural landowners. For whatever reasons, autonomy is an important value, and utilizing ground water is a technically feasible option that allows water management agencies to remain independent of the larger surface water supply systems.

The value of growth cannot be over emphasized in the area. Horry County, for example, has an aggressive growth program seeking new industry and tourism; for example, it was one of the only counties in the Southeast with a promotional booth at the 1982 World's Fair. Brunswick County is also actively seeking industrial development along the Cape Fear River and tourism along the Atlantic coastline. The values of growth have apparently overshadowed desires for autonomy in Brunswick County, as the entire county is developing a coordinated surface supply system (capacity 12 to 24 million gallons per day) to assure that the relatively small capacity aquifers in the county do not act as growth constraints in the future.

These traditional values have resulted in continued management conflicts. In North Carolina, for example, the legislature is consistently seeking mechanisms to provide for growth while maintaining environmental quality. The "Ground Absorption Sewage Treatment Act" is an example of legislation that sought to restrict septic tanks in areas of high population density and poor soil quality that would threaten ground water. Initial drafts of the legislation contained standards prohibiting septic tank systems with more than 1,200 gallon of sewage per acre per day. However, this was apparently viewed as too restrictive on growth and local autonomy, and the standards were removed in the final law in favor of local options to set septic tank densities.

As described in Section 3.2, legislation in South Carolina has always favored separate administration of water quality and water use functions. Although the reasons may be complex, a major factor in maintaining the separate functions may be that environmental quality criteria used by staff of water quality agencies might in some way be more restrictive to growth than those used in the water resources agency whose mission is to promote the development of the states water resources.

G. Legal Constraints to Ground Water Management

Many institutional and technical constraints underly problems with ground water management in the region. Although these constraints have been reduced significantly following state legislation that provided for capacity use areas, well construction standards, and septic tank permits, inadequacies still exist at the federal, state, and local levels.

At the federal level, there is no comprehensive ground water protection mechanism, such as with surface water through the Clean Water Act. This federal effort is largely an approach based on legislation to control individual sources of pollution, e.g. underground injection wells and solid waste dumps. Furthermore, the planning for ground water use and protection that existed in the past--largely the 208 Planning Program--has been scrapped.

North Carolina and South Carolina are limited in their authority to manage many aspects of ground water use. Ground water rights are conferred by ownership of the land, and the outcome of disputes are determined on a case-by-case basis in the courts (see Section 5.3). In South Carolina, Horry and Gorgetown counties are in a capacity use area where permits are required for withdrawals in access of 100,00 gallons per day (Howells 1978). In both states these well permits are granted as a matter of course to municipalities. In South Carolina no water use permit has been denied nor have pumping volumes been reduced, even in the Myrtle Beach area experiencing major drawdown and shortages (South Carolina Water Resource Commission, personal communication from staff June 1982).[1] State legislation also lacks controls to regulate stream flows, lake levels, minimum releases from impoundments, and protection of instream uses (Howells 1978).

The capacity use laws of the states generally do not address due process and just compensation if users must reduce withdrawals. The laws are generally designed to address problems as they occur rather than prevent future problems. No standards have been developed for determining priorities among users (Howell 1978).

In South Carolina, although Georgetown and Horry counties are in a capacity use area, other coastal counties suffering ground water problems are not. A consensus of autonomous local governments must request a study to receive a capacity use designation.

The capacity use designation has the potential of being an important management tool, and was invoked in the study site in South Carolina to deal with identified critical problems (Spigner,

---

[1] It should be noted that the permit systems provide the legal mechanism for information gathering and future management when population density is much higher and shortages become more acute.

Stevens, and Moser 1977). However, actual improvements in management are difficult to detect, since no restriction on water use has been implemented. The south coastal counties of South Carolina are also a capacity use area (the area of Hilton Head and Beaufort, South Carolina). Here water management problems are more critical, especially as they are affected by the high rates of pumping in Savannah, Georgia (South Carolina Water Resources Commission 1982). Yet in this most critical area little or no water conservation policies have been promulgated.

In summary the water management constraints are of three types: (1) lack of authority to manage water and lack of information about water use inherent in the riparian system and private ground water ownership; (2) divided management in quality, quantity, and solid waste disposal; and (3) limited authority excercised for permit programs and capacity use areas. Most authority affecting how and where ground water is developed remains at the local level. This pattern apparently persists because the political and financial impetus affecting when and where ground water is used is largely dependent on local development initiatives.

3.4 SOUTHEAST FLORIDA-BISCAYNE AQUIFER CASE STUDY

3.4.1 Status and Trends

This highly populated area of South Florida, which includes Dade and Broward counties, is one of the largest southeastern metropolitan regions and is continuing to grow. Although the Miami region is unique in many of its social, cultural, and environmental attributes, the high level of ground water dependency for such a large municipal region makes this case study especially interesting.

A. Population and Economics

From 1910 to 1960, the population of Dade County nearly doubled in size every ten years. In the early 1970's, the county experienced a surge in population. During 1972 and 1973 almost 50,000 new residents arrived each year, compared with an average of 33,000 during the 1960's. However, in 1974-1975 the annual increase dropped dramatically to about 10,000 persons, largely as a result of the national economic recession. Since then, population growth has resumed at approximately 25,000 a year (Metropolitan Dade County Planning Dept. 1979). Dade's 1979 estimated population was 1.519 million (Table 3-9).

It was not until after the depression and World War II that Broward County began an unprecedented pace of development. By 1970 the population of the county had increased to 620,100 and was second only to Dade County. In the period from 1970 to 1979, Broward's population increased by 56 percent to an estimated 966,100 and it remains the second most populous county in the state (Thompson 1980).

A range of population projections (Table 3-11) are based on different sets of assumptions regarding annual net migration (Univ. of Florida 1980). For example, the medium growth projection assumes annual net migration levels similar to the average in the 1970's. Under these conditions, the population of Broward County is expected to increase from approximately 966,000 in 1979 to 1.3 million in 1990 and 1.5 million by 2000. A medium growth rate in Dade County is projected to increase the 1979 population of 1.5 million to approximately 1.9 million in 1990, and 2.1 million in 2000.

TABLE 3-11: POPULATION PROJECTIONS[a]
(thousands)

County	Estimate 4/1/79	Mid-year Projections		
		1990	2000	2020
Broward	966			
Low		1,162	1,385	1,510
Medium		1,316	1,519	1,867
High		1,397	1,699	2,193
Dade	1,519			
Low		1,664	1,792	2,107
Medium		1,883	2,095	2,576
High		1,957	2,268	2,927
Total	2,485			
Low		2,826	3,077	3,617
Medium		3,199	3,614	4,443
High		3,354	3,967	5,120

Source: University of Florida Research 1980.

[a] State projections are based on three different sets of assumptions regarding annual net migration. The high projections are similar to the large migration levels of the first half of the 1970's when more people were migrating to Florida than ever before. The low migration levels are similar to those between 1975 and 1977 when Florida population growth rates were among the lowest since World War II. The medium assumptions imply annual net migration levels similar to the average in the 1970's. County projections are based on the ratio of each county's share of the total state increase from 1970-79.

The dominant employment characteristic (Table 3-12) of the two counties has been the continuing dominance of the trade and service base, which are atypically large by metropolitan standards (Metropolitan Dade County Planning Dept. 1979; Thompson 1980). Manufacturing, the third largest employer, is much less important than in most other metropolitan areas of comparable size. The atypical nature of the Dade County economy is demonstrated, for example, by the fact that the single largest employer is the School Board, followed by county government, federal government, and Eastern Airlines. Among the top 30 employers, only one is a manufacturing firm. Although the trade and services industries now account for

TABLE 3-12: EMPLOYMENT BY SECTOR, BROWARD AND DADE COUNTIES, 1980

	Broward		Dade	
Sector	1980	Percent of Total	1980	Percent of Total
Agriculture	1,740	1	4,585	1
Construction	30,400	9	41,800	6
Finance, Insurance, and Real Estate	27,300	8	51,200	7
Government	45,200	13	94,500	13
Manufactuirng	41,800	12	101,500	14
Services, Mining, and Miscellaneous[a]	82,600	24	175,400	24
Retail and Wholesale Trade	95,600	28	184,800	25
Transportation and Communications	16,200	5	71,000	10
TOTAL	340,840		724,785	

Source: Thompson 1980.

[a] Mining is a very small sector in this area. In mid-March, 1979, mining accounted for approximately 661 jobs in Dade County and 199 jobs in Broward County.

about one of every two jobs, a shift toward more services is expected, mostly in the professional services category, which includes health and educational services (Metropolitan Dade County Planning Dept. 1979).

No single industry category accounts for an excessive share of manufacturing employment. In Broward County electrical machinery, equipment, and supplies (28 percent), nonelectrical machinery (17 percent), and printing, publishing, and allied industries account for almost six out of every ten manufacturing jobs. Apparel and other textile products (23 percent), printing and publishing (10 percent), fabricated metals except machinery and transportation equipment (8 percent), and rubber and miscellaneous plastics (8 percent) account for about 60 percent of the manufacturing jobs in Dade County (Thompson 1980). Neither county is expected to become a major manufacturing center in the foreseeable future.

B. Hydrology

The hydrology of southeast Florida has been heavily modified by man through land drainage and a complex set of water storage and canal systems for regulating drainage. For the most part, the hydrologic system of southeast Florida is controlled and managed by the South Florida Water Management District (SFWMD). The District maintains and operates a system of canals, levees, pump stations, control structures in canals, and large water-conservation areas for flood control, water conservation, and salinity control. The levees impound freshwater in Lake Okeechobee and three water conservation areas (Figure 3-8). The levees also prevent overland sheet flow from the Everglades eastward through the agricultural and urban coastal areas.

Canals drain the urban coastal area and also serve to transfer water from the water conservation areas and Lake Okeechobee to the east coast to replenish the Biscayne Aquifer and to retard saltwater intrusion. Flow in the canals is regulated to maintain ground water levels in the urban areas and bordering farm lands at levels low enough to prevent flooding. The volume of outflow to the ocean varies, depending upon rainfall. At the end of the rainy season most control structures are closed to conserve freshwater and prevent saltwater from moving inland (Klein and Hull 1978).

Water releases from Conservation Area 3 are made to the south during the year to sustain plants and animals in the Everglades National Park. During much of the dry season, water-levels near the coast are maintained by direct seepage from the water conservation areas. During prolonged drought, the canals transfer water from Lake Okeechobee through the conservation areas to points of need along the coast. Lake water is shared by local municipalities, Everglades National Park, and agricultural interests. This sharing leads to the need to balance urban and agricultural flood

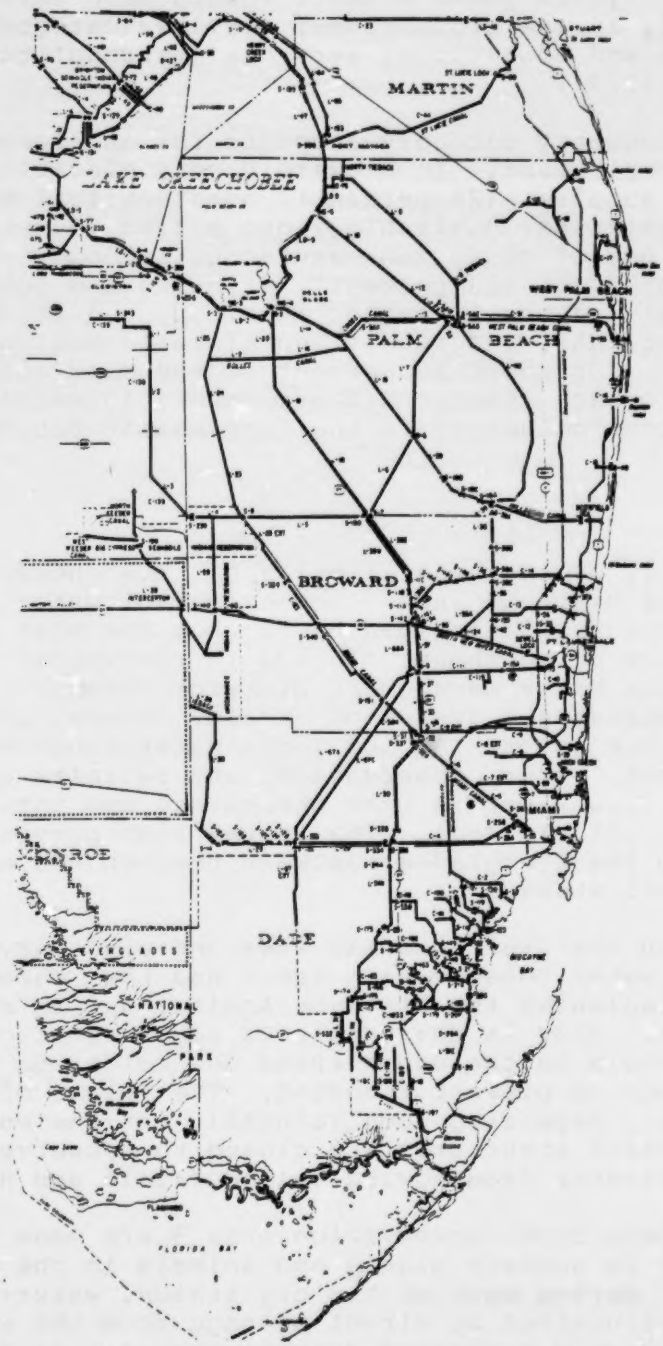


Figure 3-8: Hydrologic structures and hydrologic features of the South Florida Water Management District.

Source: Klein and Hull 1978.

control against water conservation and environmental protection--particularly the preservation of the ecosystem of the Everglades National Park. The major challenge to water management in south Florida is to achieve the multiple objectives of the various interests involved with a system of canals and levees that was originally designed to provide flood control and land drainage.

The Biscayne Aquifer that underlies Dade and Broward counties is the hydrologic unit of water-bearing rocks that carries unconfined ground water in southeastern Florida. Almost the entire potable, industrial, and agricultural water supply for this area comes from the Biscayne Aquifer. The Aquifer underlies all the coastal areas and most of the Everglades northward to approximately the Broward-Palm Beach County line. It is a highly permeable wedge-shaped aquifer that is more than 200 feet thick in coastal Broward County, and thins to an edge 35 to 40 miles inland in the Everglades. This unconfined aquifer is so close to the surface that normal distinctions between ground and surface water are not meaningful.

The limestone and sand that form the upper surface of the aquifer readily absorb rainfall and move it rapidly to the water table. Other sources of recharge to the aquifer are: (1) connate ground water[1] of inferior quality along the upper reaches of the Miami, the North New River, and the Hillsboro Canals in Broward and Palm Beach counties (northwest of the limits of the Biscayne Aquifer) that moves eastward during dry seasons; (2) water from Lake Okeechobee released by the South Florida Water Mangagement District into the Miami Canal during the later weeks of the dry seasons to replenish the Miami area; and (3) effluent from septic tanks, certain sewage treatment plants and disposal ponds scattered throughout the urban area. Recharge from canals is greatest during the dry season, December to May, when canal levels are maintained above the water table.

Discharge from the aquifer is by evapotranspiration, by ground water flow to canals and to the sea, and by pumping from wells. Well yield is only a small part of the total discharge from the aquifer, but during the dry season its importance is amplified because if occurs when total recharge and aquifer storage are smallest.

Although ground water quality degrades toward the west and north in both counties, all of the water is of drinking water quality in terms of chloride (excluding those areas affected by saltwater intrusion). In general, the water is hard and contains varying amounts of dissolved iron.

---

[1] Connate water is sea water that was deposited simultaneously with the geologic formation in which it is contained.

One of the prime problems of water treatment for municipal supplies is the high organic content of the raw ground water. Color of the water in southeast Florida is related to the proximity of the thick organic peat soils of the Everglades. Color is high in the raw water from the Miami Preston well field; in contrast, the color at the Miami-Orr and Key West fields is much lower because of the greater distance from the organic soils. Chlorine used in the treatment process has been shown to produce halogenated organics (principally trihalomethanes), some of which may be carcinogenic (Rook 1975). Dade County is investigating the possibility of using chloramine (chlorine and ammonia) which does not produce trihalomethane.

One of the most important factors in flood control and water management in Southeast Florida is the hydraulic connection between the Biscayne Aquifer and the canals that dissect the aquifer. This interconnection brings about benefits and problems. The benefits are: (1) flood prevention by the rapid removal of excess water to the ocean through operation of control structures in canals; and (2) reduced saltwater intrusion through the movement of water into the canals from the interior areas and subsequent infiltration to the aquifer. Problems related to good aquifer-canal interconnection are: (1) the movement of saltwater into the aquifer along the coast and tidal canals during times of low water; and (2) the threat of pollutants entering the aquifer from the land surface or from canals. The degree of connection can be affected by sediment accumulation along the bottom of the canals. Thus, the rate at which a canal can recharge or discharge water to or from an aquifer may change over the years because of the accumulation or removal of channel bottom sediments. Principle areas of concern are the canal reaches in the vicinity of the major municipal well fields. The canal bottom sediments tend to retard but do not prevent the infiltration of canal water into the aquifer in these areas.

Dade County ground water use has developed primarily as a result of heavy population growth. Dade uses more ground water for public water supply than any other county in the South Florida Water Management District. In 1975, twenty Dade County potable water suppliers withdrew ground water from the Biscayne aquifer at an average rate of 247 mgd to serve a population of approximately 1.8 million people (South Florida Water Management District 1977b). The Miami-Dade Water and Sewer Authority is the largest supplier of potable water in the District. Its well fields account for 78 percent of the total water pumped for domestic use and supply 72 percent of the county's population.

In addition to providing potable water for domestic use, the Biscayne Aquifer is the sole source for irrigation water for agriculture in Dade County. Twenty-five percent (87 mgd) of the ground water withdrawn was used for agriculture. The remaining ground water was self-supplied by industry and accounted for about 9.3 mgd in 1975.

While ground water supplies less of the total water requirements in Broward County (72 percent) as compared to Dade (99 percent), the pattern of water use in Broward is similar to that of Dade County. The major use of ground water is for public water supply with all of the potable water withdrawn from the Biscayne Aquifer (135 mgd). In 1975, ground water withdrawals ranged from 47.7 mgd for Ft. Lauderdale, which serves a population of approximately 226,000 people, to Coral Springs Improvement District's 0.14 MMgd withdrawal which supplies 855 people. Per capita consumption ranged from 259 gallons per day for the City of Pompano Beach to 71 gallons per day for Davie Utilities Company (South Florida Water Management District 1977b).

Dade and Broward counties differ with respect to the number of potable water suppliers. In 1976, 18 major utility companies operated 37 well fields and water-treatment plants in Dade County. In Dade County, water is supplied to consumers by 27 certified utilities, of which only 15 operate their own wells and treatment facilities. In addition, approximately 100,000 people are still served by individual wells (Metropolitan Dade County Planning Department 1979). Broward County has 52 community water systems of which 27 have at least one mgd plant capacity. Approximately 21,400 people are presently being supplied 3.25 mgd of potable water from an estimated 8,560 private wells in Broward County (Broward County Planning Council 1981).

3.4.2 Problems and Issues in Ground Water Development

The Biscayne Aquifer is vulnerable to contamination from several sources, including:

- Saltwater intrusion;
- Leachates from active and closed landfills;
- Leakage from underground holding tanks for various petroleum products and other chemicals;
- Agricultural runoff;
- Urban stormwater runoff;
- Improper and/or over use of septic tanks;
- Effluents from domestic and industrial waste treatment facilities;
- Accidental or indiscriminate spills; and
- Effluent from leaking sewer systems.

These problems are compounded by existing environmental conditions which tend to facilitate such contamination--large quantities of rainfall, shallow depth to the water table, and a highly permeable aquifer. The impacts of contamination can be critical when pollutants enter the ground water near a pumping water supply well field, since the withdrawal of water from the aquifer increases ground water flow towards the well in the area surrounding the point of withdrawal. While progress has been made in recent years, there are still many sources of pollutants contributing to the degradation of ground waters.

A. Wastewater

Point sources of pollution, which are handled by conventional treatment systems, have been the primary target of pollution abatement efforts. Until the early 1970's, millions of gallons of poorly treated or untreated domestic wastes were discharged daily into the inland surface waters of Dade County. Since that time, this major source of pollution has been substantially abated. Domestic wastewater treatment has been significantly upgraded and by 1990 all discharges to inland surface waters are planned to be phased out (Metropolitan Dade County Planning Department 1979).

In Broward County there are nearly 100 plants ranging in capacity from several thousand gallons per day to more than 35 mgd. Altogether, these plants have a capacity to treat up to 166 mgd of sewage of which about 66 mgd of treated effluent are discharged to the ocean, 5 mgd are discharged through deep wells, and the remaining 95 mgd are discharged either to surface waters or indirectly into the Aquifer through drainfields, percolation ponds, or land irrigation (Broward County Planning Council 1981).

Improvements also have been made in industrial wastewater treatment and disposal practices. There are presently four major types of industries that release effluents to sewage systems. Of these the dairy and textile industries release the greatest amount of effluents, but the plating and chemical-photo industries discharge the most potentially toxic effluents. Although pretreatment requirements exist, numerous small industrial wastewater sources remain to be dealt with. And although the quality of Dade County's inland waterways has improved, all but two major canals in the extreme southern portion of the county--Canal III and Mowry Canal--still fail to meet one or more water quality standards.

B. Landfills

In 1980, there were four active landfills in Broward County; of these, two are near the coast and located within the area identified as being intruded with saltwater and consequently present no threat to drinking water supplies. The other two landfills, the

Central Disposal Landfill in the north and the Davie Landfill in the west overlie portions of the aquifer that contains good quality water. The landfills have contaminated pockets of the aquifer in their vicinity. A study conducted by the Broward County Environmental Quality Control Board (1981a) indicated that contaminated ground water is moving southeast toward the South New River Canal. The rate of movement of the plume is variable depending, in part, on the frequency and duration of drainage of the area. The maximum rate of movement from the sludge lagoon has been estimated to be one foot per day to 0.25 foot per day. The canal is approximately 1,800 feet south of the lagoon.

Since February 1952, metropolitan Dade County has operated a solid-waste disposal facility on one square mile west of the city of Hialeah. In the mid-1970's personnel of the Department of Environmental Resource Management and the Department of Public Works of Dade County become increasingly aware of and concerned about the potential ground water pollution posed by the chemical leachates from the facility. The downgradient migration of leachate is influenced by the continuous withdrawals from a group of municipal wells of the Miami-Dade Water and Sewer Authority, about 3 miles east of the waste disposal area. The average quantity of ground water containing leachate moving toward the well field was estimated to be about 227,000 cubic feet per day or 1.7 MGD. This constitutes about 1.5 percent of the average daily withdrawal of the municipal well field.

Concentrations of dissolved material in ground water--material that originates at the disposal site--decrease with depth in the aquifer. Leachate has migrated more than 0.5 mile downgradient from the source. The occurrence of leachate-derived materials in ground water at distances appreciably greater than 0.5 mile is difficult to determine because dispersion and rainfall dilute the leachate plume to concentrations close to background concentrations.

Establishment of a new auxiliary well field at a capacity of 40 MGD and less than 2 miles east of the disposal facility probably will increase the ground water gradient in the area and increase the rate of migration of the leachate (Mattraw, Hill, and Klein 1978).

C. Saltwater Intrusion

Saltwater intrusion affects the entire coastal zone of the Biscayne Aquifer. Saltwater extends inland from the coast and along tidal streams and canals. It moves inland and upward in response to low ground water levels, and seaward and downward in response to high ground water levels. Figure 3-9 shows the extent of saltwater intrusion as of 1980.

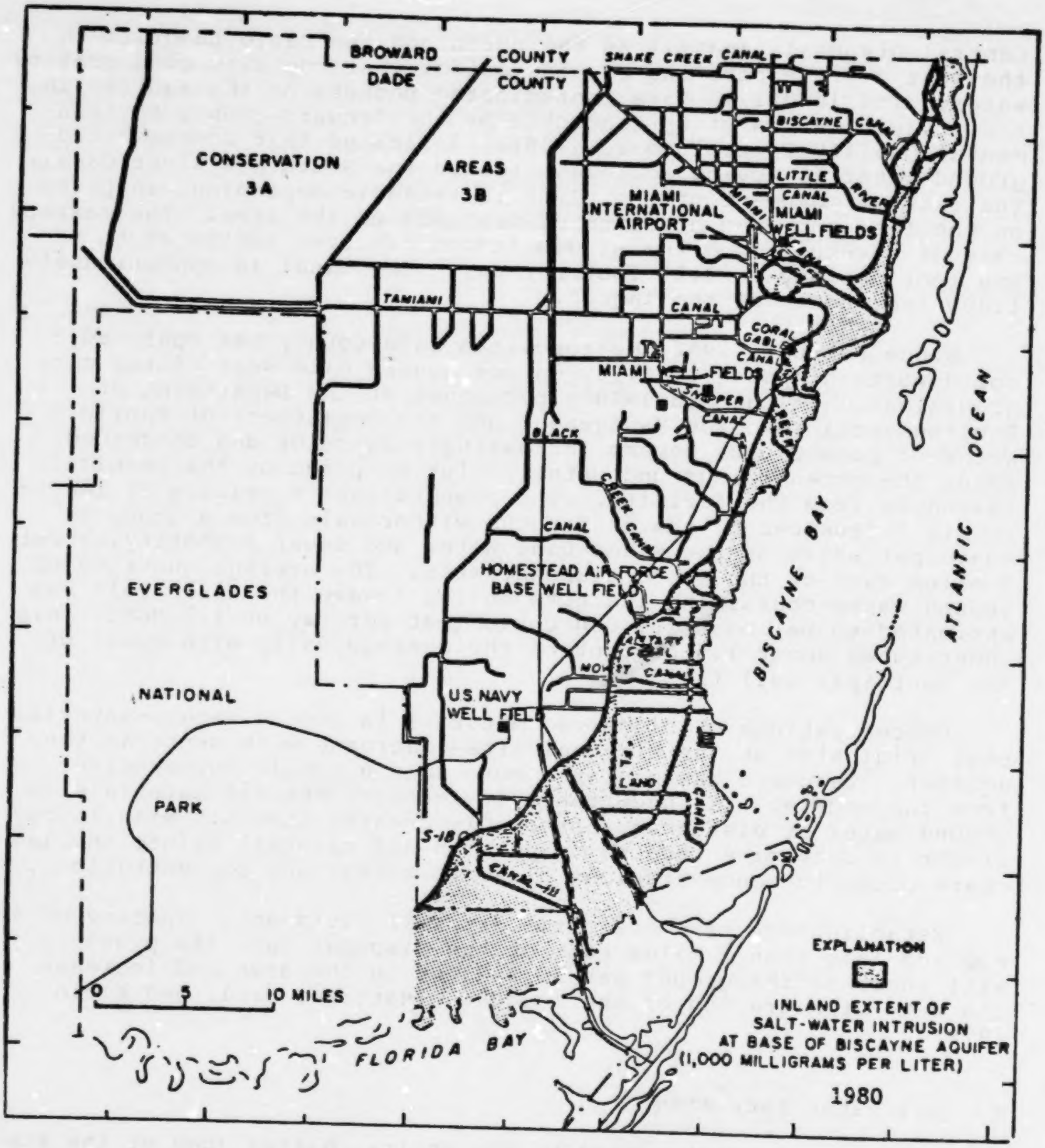


Figure 3-9: Southeast Florida showing inland extent of saltwater intrusion 1980.

Source: U.S. Geological Survey 1981.

Dade County has experienced salt water intrusion problems for many years. In 1971 salt water intrusion was in close proximity to two well fields. The saltfront was within a mile of the Miami Springs well field and within 1500 feet of the Air Base well field (Hull and Wimberly 1972). Even further intrusion occurred and by 1974 the salt front migrated to within 0.7 mile of the City of Miami well field in Miami Springs and into the Air Force Base well field.

Problems with salt water intrusion in Broward County are in general associated with finger canals without salinity barriers.[1] Uncontrolled canals caused salt water intrusion in Pompano Beach. These finger canals lower fresh water heads and allow for direct intrusions of sea water to inland locations (Tarver 1964). The same conditions basically existed in the area of Ft. Lauderdale's Prospect well field until salinity control structures were installed on the major canals and feeder canals were constructed to convey fresh water into the upstream side of those structures (Sherwood, McCoy, & Galliher 1973). While saltwater intrusion must be monitored continuously, its advance has been checked and it is no longer considered a major problem.

The Management District maintains minimum ground water levels to prevent salt water intrustion and to provide recharge to coastal well fields. Minimum ground water levels are maintained by salinity barriers and, during the dry season, by the discharged of fresh water from interior storage areas such as Lake Okeechobee and the Conservation Areas, to the coast (South Florida Water Management District 1977a).

D. Urban and Agricultural Runoff

With the incidence of any large storm, especially at the beginning of the rainy season, accumulated contaminants flow with the runoff water overland and through storm drains into canals, lakes, bays, and through seepage devices into the shallow water table aquifer. In addition to bacterial contamination, storm outfalls discharge suspended solids, nutrients such as nitrates, and potentially toxic chemicals. Other constituents of urban runoff include hydrocarbons and metals from roadways and parking lots, biocides and fertilizers from landscape maintenance, fecal material from domestic pets, and household and industrial chemicals. Movement to ground water is facilitated by floor drains, storm drains and sumps, and other soakage and detention facilities (Metropolitan Dade County Planning Department 1979).

---

[1] Finger canals are small canals used to increase the availability of waterfront property. Salinity barriers are small dams across canals that prevent salt water from moving farther inland.

The quality of this storm water runoff can violate standards set for the discharge of wastewater effluents (Mattraw and Sherwood 1977; also see Section 4.3). However, a study conducted by the Dade County Department of Environmental Resource Management (1979) indicated that spreading stormwater onto the surface of the ground or injecting it into the subsurface has the benefit of reducing the lifetime of constituent bacteria. The attenuation properties of the underground strata are more effective than surface water as a receptor of storm water runoff (Dade County DERM 1979).

High nitrate and potassium concentrations strongly indicate that agricultural fertilizers also are a source of ground water degradation in south Dade County. Much of the nitrate was entering the ground water system through leaching of agricultural fertilizer. The highest levels were noted in planting and harvesting seasons when no cover crops exist (Dade County Department of Environmental Resources Management 1980a). Nitrate levels have recently been found to exceed both state and local drinking water standards in some south Dade canal waters and in certain domestic wells. Although the high nitrate levels are very localized, two public well fields also draw their water supplies from this area.

E. Septic Tanks

Septic tanks are another possible source of pollution to the Biscayne Aquifer. Although their effects under normal conditions are negligible and assist aquifer recharge, several studies in Dade and Broward Counties have shown that septic tanks can affect the water quality in the aquifer to depths of at least 20 feet.

It is estimated that there are approximately 300,000 septic tanks in Dade County, many of which exist in areas where new or proposed well fields have been or will be built (Dade County Department of Environmental Resources Management 1980a). There is a high bacteriological and virological content associated with septic tank effluent. Because of the high density of septic tanks in some areas and the lack of knowledge as to the survival and travel rates of bacteria and viruses, there is concern as to their effects on drinking water. There has recently been a proposal in the legislature to double the land area required for septic tanks and to remove the grandfather provision for plotted lots; also, there would be a surcharge added to permits to fund a definitive study to determine proper spacing for septic tanks.

Because the newer well field areas are removed from the more heavily populated eastern sections of Dade County, sewers are unavailable. The zoning in these areas is also lower in density, thus allowing, by law, the use of septic tanks. At the present time the only method used to ensure proper use of septic tanks in these newly developing areas is restrictive covenants associated with property deeds. Such covenants may restrict the kinds and intensities of uses, thereby minimizing the possibility that hazardous materials or excessive flows will reach the ground water. Enforcement of these covenants is difficult, especially for commercial facilities which might change from an innocuous use such as warehousing to an active chemical process such as dry cleaning.

F. Storage Tanks

Storage tanks are used throughout the area for petroleum products, toxic chemicals, or other liquid substances. These facilities are restricted to industrial and commercial zoning classifications. It is not presently known how many storage facilities exist, due largely to the lack of permitting procedures. Since 1973, however, a storage information sheet has been required for any building permit utilizing such facilities in Dade County.

Leaks from storage tanks often are hard to detect until a water or fume problem exists. Many storage tanks (e.g., gasoline) are placed in the ground and corrosion and eventual leakage can go unchecked for years unless the tanks are periodically raised and inspected. This is very costly and rarely done. New regulations concerning storage tank installation and use are being developed for Dade County.

Several incidents of ground water contamination have occurred from leaky storage facilities. In 1971, 1.5 million gallons of solvents, including hydrocarbons, were estimated to have been released to the ground water under Miami International Airport, less than one mile south of the Hialeah Miami Springs well field. While corrective actions have apparently been effective in controlling the spread of this material, it clearly illustrates the hazardous of underground storage and transport.

Since 1972 over 50 cases of storage tank leaks have been reported in Dade County alone. Several of the larger cases are described below:

- In September 1973 a gasoline leak occurred at a South Dade station. The surrounding homes were on private wells. Emergency action was taken by Dade County and Florida Water and Utilities to place over 65 homes on public water, at a cost of $66,000.
- In 1977 two cases of domestic wells contaminated with petroleum occurred. Both of these were attributed to underground storage tank leaks. Only in one case, however, could the leak be pinpointed (a gas station) and corrected. In 1980 the area's water still contained some traces of the products, but not at hazardous levels.

- In the fall of 1977 leakage from the underground storage tanks of an industrial park was discovered during a contamination incident of a public water supply well field in North Dade. The wells are located immediately to the southeast of an industrial park, and were found to contain trace levels of synthetic chemicals associated with industrial activities. The contamination of the well field stopped water service to approximately 90,000 people for a three day period.

- In August 1979 a bulldozer, while clearing some trees, broke a major fuel transmission line. This line brought jetfuel from Miami International Airport to Homestead Airforce Base. As of December 1980 approximately 50,000 gallons of jetfuel had been pumped from the ground water and the clean-up process was still ongoing.

G. Sewer Systems

Many areas of Dade County are not allowed to utilize septic tanks due to high density or type of land use. Although sewers required in these areas more adequately protect the ground water than septic tanks, some problems have been associated with these systems.

Leakage from a sewer (exfiltration) is common in areas where the pipe is not submerged below ground water. Drawdown from a well field, for example, can lower the water table so that sewer lines are not submerged. This allows untreated sewage to leak from the pipe and percolate to the ground waters below. It is estimated that sewers have an exfiltration rate of 200 gallons per inch of pipe diameter per mile per day (Dade County Department of Environmental Resources Management 1980a). This much exfiltration of untreated sewage indicates that, although sewers are a more acceptable form of waste disposal than are septic tanks, their use will not eliminate degradation of ground water supplies.

H. Industrial Chemical Pollution

The ground water supply for one of Dade County's largest well fields, the Preston/Hialeah field, has higher concentrations of volatile organic compounds (VOC) in well areas surrounded by industrial uses (Dade County Department of Environmental Resources Management 1980b). Elevated VOC levels were generally found to be fairly high downstream of the industrial areas, and each area where VOCs were detected had some industrial activity located upgradient.

Other North Dade well fields also have shown high levels of synthetic organics. These areas all contain industrial land uses within the well field cones of influence. Several wells had levels above the 100 parts per billion (ppb) standard for total trihalomethanes set by EPA (Dade County Department of Environmental Resources Management 1980a).

I. Small Generators of Hazardous Waste

Another important industrial or commercial source that could have a severe impact on ground water quality are generators of hazardous or toxic wastes. According to a study conducted by the Broward County Environmental Quality Control Board (1981), the larger and consistent generators of hazardous or toxic sludge follow an orderly manifest and disposal procedure in compliance with RCRA. However, this is not the case with the small quantity generators (less than 1 ton per month) who are not required to comply with the manifest provisions of Resource Conservation Recovery Act (RCRA). The small quantity generators who want to follow correct disposal practices find themselves at a severe disadvantage. If they only generate a few gallons per month and dispose of a partial drum infrequently, the company learns that: (1) the disposer will not handle the material if they do not have an EPA number, which the EPA says they do not need; and (2) the disposal charge for a drum is generally in the range of $90-$150, frequently with a minimum charge of $300. However, the disposal firms will not accept the material without an "analytical profile" which can cost in the range of $300 to 500. This also involves the preparation of extensive and complex paper work. Thus, the cost to dispose of one partial drum can easily exceed $500 and may require hiring a consultant to prepare the paperwork.

Obviously, under present conditions the proper disposal of a small quantity of hazardous or toxic waste can become a major problem and is very costly to a small company. The Environmental Quality Control Board is extremely concerned that due either to regulatory frustration and/or high cost, the incidence of illegal disposal is almost certain to increase. Of the 52 hazardous waste generators in Broward County, 20 do not generate quantities large enough to require an EPA number (Howard 1982). The cumulative effect of illegal dumping from these small generators could have disasterous consequences for the quality of ground water in the area.

J. Ground Water Information Systems

A number of agencies are involved in monitoring the quality of water in the Biscayne Aquifer--the U.S. Geological Survey (USGS), Broward County Environmental Quality Control Board, Dade County Department of Environmental Resources Management, the South Florida

Water Management District, and individual businesses. However, there is no regional monitoring of ground water that gives an overall picture. Generally, attention has been given to individual sources of pollution with monitoring wells for the particular source rather than monitoring the Biscayne Aquifer as a system. While, for example, the USGS may monitor existing wells or monitor wells may be set up around a problem landfill, little is known about background characteristics or where pollution exists in the aquifer as a whole. Almost no monitoring is done outside the cones of influence of existing wells.

Through a cooperative program with the USGS, the Broward County Environmental Quality Control Board maintains a surface water quality monitoring network in the canals of Broward County. This network includes 42 sites throughout the county. Approximately half of these sites are sampled at least twice a year, and the other half are sampled periodically as the need demands (Broward County Planning Council 1981).

However, the efforts of the USGS and Broward County Environmental Quality Control Board to setup a network of monitoring wells have been hampered by financial constraints. The allocation from the county budget was reduced recently by 50 percent and the USGS reduced its matching funds commensurately. Prior to this cooperative effort, monitoring was done on a case by case basis if a well happened to be in place around an industry that needed to be checked.

When the Environmental Protection Agency designated the Biscayne a sole source aquifer in 1979, impetus was provided to expand the well field water monitoring program into an areal ground water quality network. This network has been designed to determine baseline ground water quality throughout the county, to indicate where more intensive monitoring is needed, and to alert officials to major problems before they become critical.

K. Water Quality Management

The loss of 208 funds is another problem that has a direct impact on the ability of these counties to continue to monitor and plan for water quality management. In Broward County, the only water quality planning and information system resulted from 208 funding. Some people feel that the state will not pick up the ball and provide local planning money and these efforts will decrease. This will lead to a lack of scientific data needed in order to properly manage the system. Further, although state programs dealing with ground water quality will continue, enforcement may suffer with cutbacks in federal support (Walker 1982). This can be particularly troublesome in this area because of the intense pressure for development and the fragility of the environment.

Finally, the Florida Department of Environmental Regulation (DER) has begun to divest itself of some of its responsibilities for water quality management (e.g., dredge and fill operations and stormwater runoff) and is passing them on to the South Florida Water Management District. By law the DER is responsible for water quality while the District is responsible for water quantity. While the District is fully aware of the necessity of dealing with both concerns together, it nevertheless is somewhat reluctant about taking on DER's water quality responsibilities. This reluctance stems, in part, from uncertainty about the source of additional funding to carryout these new responsiblities.

L. Ground Water Use Management

As Broward and Dade Counties began to develop, the two principal objectives of water management became the maintenance of water supplies and the prevention of flood damage. In recent years these two objectives have become increasingly divergent. A basic problem is that south Florida's physical environment is not conducive to storing water from one year to the next. Surface storage areas are shallow and subject to evapotranspiration. Most of the water supply is stored in the Biscayne Aquifer which must be protected from saltwater intrusion.

Though the problem of saltwater intrusion has been dealt with since the mid-1940's, the extremely low water levels experienced during the 1970-1971 drought, for example, increased the threat of contaminating drinking water supplies. In Dade County this forced a 20 percent reduction in the amount of water pumped from major well fields and the imposition of use restraints (Metropolitan Dade County Planning Department 1979).

Flood protection has involved the construction of storm drains and canals to lower the water table by discharging "excess" water to the ocean. This increases peak flows in some drainage canals to capacity during major storm periods, and diminishes recharge and water supplies by rapidly discharging surface waters to the ocean. Prior to the storm season, the level of Lake Okeechobee is lowered so the lake can hold the water from the summer storms. However, if the rainfall is below normal, the lake's water supply is not fully replenished nor is the Biscayne Aquifer fully recharged. In years of below normal rainfall, the water is sent through the canals from Lake Okeechobee to recharge the aquifer and provide drinking water. In prolonged drought, the lake does not have sufficient water for the canals, saltwater intrusion increases, and water use is constrained.

The management of ground water use must balance the demand for development, drainage, and flood control against the increased demand for potable water. If the area experiences typical rainfall patterns, everything is fine with respect to management of water use; otherwise, either emergency water rationing plans may be implemented or floods may occur.

3.5 HENRY COUNTY, GEORGIA

3.5.1 Status and Trends

Henry County, Georgia is located 25 miles directly south of the metropolitan Atlanta Region. This lies north of the Fall Line, the boundary between the Piedmont and Coastal Plain physiographic provinces (Figure 3-10). Historically the county has been a rural agricultural area, but it is increasingly becoming more industrialized largely because of the growth of Atlanta. The location of the study area adjacent to a rapidly growing urban area will continue to affect both the quality and quantity of water resources (U.S. Army Corps of Engineers 1978). This county was selected for study as an area indicative of growth in the Piedmont--an area of the Southeast which is undergoing significant population and industrial growth. Industrial and municipal use of ground water is increasing because of concerns over the reliability of surface water supplies.

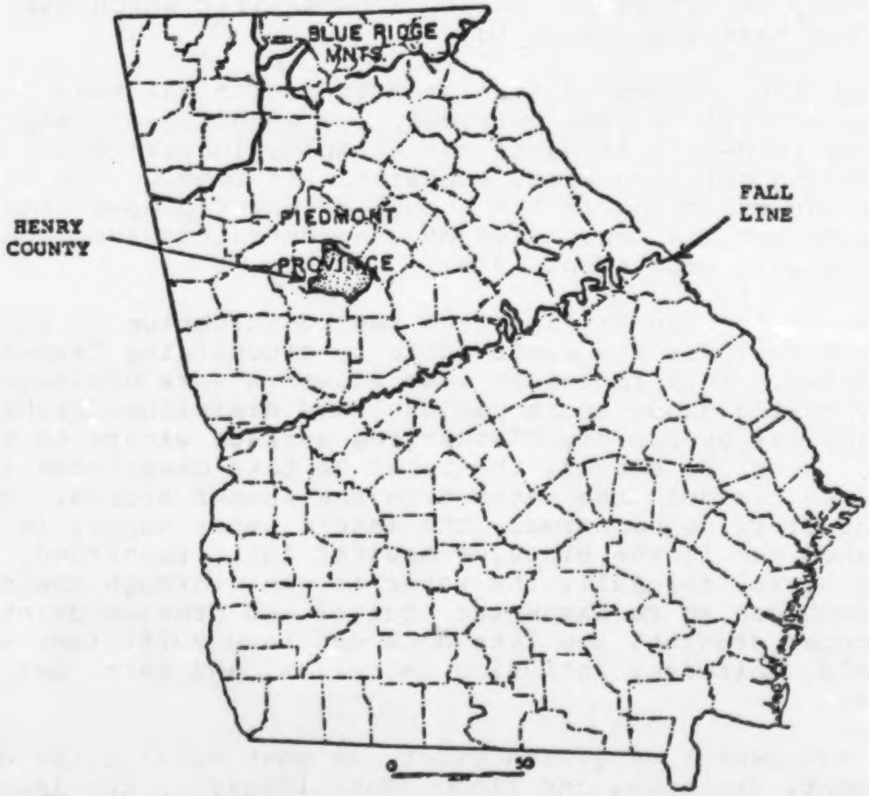


Figure 3-10: The Piedmont Province of Georgia.

A. Population and Economics

The population of Henry County according to the 1980 census was 33,531--3,455 urban and 30,076 rural. This represents a 71 percent increase in population since the 1970 census. Between 1950 and 1960 the county experienced net outmigration. Since 1960 it has experienced a net inmigration attributed to the growth of the Atlanta area (Robertson 1977; Georgia Dept. of Industry and Trade 1979). Major cities in Henry County are Hampton (pop. 1,864), Locust Grove (pop. 1,124), McDonough (county seat) (pop. 2,606), and Stockbridge (pop. 2,171).

Henry County is included in the McIntosh Trail Area Planning and Development Commission (APDC), one of the fastest growing areas of Georgia. Since 1970 Henry County has been 17th out of the 159 counties in Georgia in rate of growth. The eight counties in the McIntosh Trail APDC are located midway between the "Golden Triangle" of Atlanta, Macon, and Columbus, and are prime areas for industrial growth because of their proximity to large, urban markets (Robertson 1977).

Three out of five workers in the McIntosh Trail APDC are employed in textiles (Robertson 1977). Henry County has an increasing industrial base although the largest employers are service industries such as retail trade and public services. There are 63 construction firms in the county and 32 manufacturing firms. Table 3-13 lists the largest county manufacturing firms and Table 3-14 shows a breakdown on industry employment. The firms located in Henry County can draw upon the surrounding counties of Butts, Clayton, Newton, Rockdale, and Spalding to augment their labor force (Georgia, Dept. of Industry and Trade 1980). Many residents of these rural counties commute to the Atlanta area for jobs. In Henry County, this includes approximately 50 percent of the labor force.

There are several indicators that Henry County will continue to grow in the future. The Henry County Industrial Authority established a 100-acre industrial park near Hampton, with the potential for expansion to 700 acres. Second, the county has 100 percent freeport status which means that raw materials, work-in-process, and finished goods inventory to be shipped outside the state are exempt from property tax. This is beneficial to industry already located in the county and provides an incentive to new industrial location. Third, Henry County is accessible--it has two railroads, (one on each side of the county), and two four-lane highways providing direct access to Atlanta and Hartsfield International Airport (Robertson 1977).

TABLE 3-13: LARGEST COUNTY MANUFACTURING FIRMS

Firm	Products	Jobs
McDonough: McDonough Power Equipment, Inc.	lawn mowers	463
Hampton: Southern States, Inc.	high voltage disconnects	326
McDonough: Dowling Textile Mfg. Co.	hospital apparel	220
Locust Grove: Smead Mfg. Co.	filing supplies	200
*Hampton: Georgia-Pacific Corp.	asphalt roofing	100
McDonough: Hoyne Industries, Inc.	mirror tiles	100
*Stockbridge: International Paper Co.	corrugated boxes	60
Stockbridge: Vulcan Materials Co.	crushed stone	59
McDonough: Simmons Mfg. Co.	valves for water systems	55
McDonough: Gang-Nail Structures, Inc.	wooden roof trusses	49
Stockbridge: Mid-State Drainage Products	corrugated steel	36
Stockbridge: Ecodyne Cooling Products	concrete cooling towers	32

*Company not operational until October, 1980, therefore, employment figure not included in employment summary.

Source: Georgia Dept. of Industry and Trade 1980.

TABLE 3-14: COUNTY EMPLOYMENT SUMMARY INDUSTRIES

Industries	Firms	Total
20 Food	2	10
21 Tobacco	0	0
22 Textile	0	0
23 Apparel	3	274
24 Lumber	3	71
25 Furniture	2	4
26 Paper	1	200
27 Printing	1	12
28 Chemicals	1	11
29 Petroleum Refining	0	0
30 Rubber/Plastic	0	0
31 Leather	0	0
32 Stone/Clay/Glass	6	218
33 Primary Metal	1	36
34 Fabricated Metal	4	129
35 Non-Electrical Mach.	1	463
36 Electrical Machinery	1	326
37 Transportation Equip.	0	0
38 Instruments	0	0
39 Miscellaneous Mfg.	0	0
Manufacturing	26	1,754
Non-Manufacturing	399	12,899
Total	425	14,653

Source: Georgia Dept. of Industry and Trade 1980.

B. Water Resources and Supply Systems

Major surface streams in Henry County such as the Towaliga River, Walnut Creek, James Creek, and Tussahaw Creek are in the Okmulgee-Altamaha River drainage that empties to the Atlantic Ocean. In contrast, counties to the west, north, and much of metropolitan Atlanta are in the Chatahoochee River drainage that ultimately empties to the Gulf. Some of the creeks serving Henry County are impounded in the adjacent Clayton County to serve neighboring cities.

As discussed in subsequent sections, Henry County's ground water resources are poorly defined but occur in fractures in the bedrock characteristic of the Piedmont region. In 1980, ground water used in Henry County was largely for rural domestic and public supply purposes (see Table 3-15). No ground water was used for industrial purposes or for irrigation. Ground water accounted for 47 percent of the total water used in Henry County (4.6 million gallons per day) in 1980. As indicated above, surface water for the Atlanta metro area and the rural areas immediately south of Atlanta come largely from the Chattahoochee River, its tributaries, and Lake Lanier. Upstream from the Chattahoochee's confluence with Peachtree Creek the water quality is good. Downstream the water is "moderately" polluted as a result of treated wastewater discharges, combined sewer overflows, and urban runoff from the Atlanta area (Atlanta Regional Commission 1976). This is forcing the areas south of Atlanta to look elsewhere for surface water supplies or to develop ground water resources. Both municipal and county governments are responsible for water supply in Henry County. The Henry County Water Authority utilizes the Towaliga River as a raw

TABLE 3-15: GROUND WATER USE IN HENRY COUNTY IN 1980
(millions gallons/day)

Category	Total Used
Public Supply	0.45
Domestic (rural)	1.72
Livestock	.01
Self-supplied Industrial	0
Irrigation	0
Thermoelectric	0
Hydroelectric	0
	2.18

Source: Unpublished USGS data 1982.

water source and furnishes water to several communities in the county. The community of McDonough (pop. 2,606) utilizes Walnut Creek as the main water source and also uses some ground water while Hampton (pop. 1,864) obtains all of its supplies from ground water.

3.5.2 Problems and Issues in Ground Water Development

A. Uncertain Role of Ground Water Supplies

Future growth in Henry County will increase concerns about the adequacy of water supplies. For example, a study conducted by the State of Georgia in 1975 predicted future possible water shortages south of Atlanta (Robertson 1977). Governor Busbee has designated four counties around Atlanta as ripe for growth--Fayette, Henry, Spalding, and Coweta--due to ease of access to the metro airport and the availability of a labor force. However, a Corps of Engineers study in 1978 on these four counties indicated potential water supply problems and recommended a regional approach to deal with water concerns.

Because of these concerns, Henry County has constructed five connections to purchase water from Clayton and Dekalb counties and the City of McDonough. These connections together with planned expansions will allow a capacity of about 8 million gallons per day (Georgia Dept. of Industry and Trade 1980). The regional water supply plan drafted by the Atlanta Regional Commission (1981) is based upon development of surface water resources and wiser use of those resources. The Atlanta region has included northern Henry County in its water use projections based on its close economic and geographic ties with Atlanta.

In comparison to the large known ground water resources available in the Georgia Coastal Plain, the known ground water supplies in the Piedmont Province appear to be limited. However, very few scientific ground water investigations have been performed in the Piedmont Province to delineate the extent and quantity of ground water resource. What information is available comes from the municipal well records and the untested opinions of local well drillers. The well drillers seldom perform a long-term pump test to determine specific discharge of a newly drilled well. If their client needs only 10 gals per minute, then the well drillers stop drilling when they estimate they have reached that point.

In the Piedmont area south of Atlanta, ground water availability is further complicated by dendritic drainage in which stream channels have developed independently of the underlying bedrock (Cressler 1982). Because of this drainage pattern, high-yield wells commonly are in "odd" places such as ridge tops and on steep slopes. Many of the wells derive water from horizontal stress-relief factures 400 to 600 feet deep. The recharge mechanism for such fractures is not fully understood. Traditional methods of well siting, based mostly on topography, have limited application when looking for ground water in the Piedmont area south of Atlanta (Cressler 1983).

Prior to World War II many small municipalities (now included in Metropolian Atlanta) utilized ground water as their sole water supply. Following the construction of large federally funded reservoirs the municipalities in the Piedmont Province have become dependent upon surface water supplies. Many of the old municipal water wells are still in use as auxiliary sources for times of drought (Mann 1983).

The U.S. Geological Survey recently conducted a study of ground water availability in the Piedmont (USGS Open-File Report 82-569) and concluded that the ground water resources in the Atlanta area are just barely tapped now and that there is potential for further development (Cressler 1982). Locally, the aquifers are recharging and are not being depleted. However, the mechanics of aquifer recharge in the Piedmont, particularly the location of recharge areas for deep horizontal fractures, are not well known. Wells in the Piedmont can yield as much as 100-450 gpm, but the water can be difficult to find and better techniques for locating ground water supplies are needed. Because of the uncertainty concerning ground water in the Piedmont, it is unclear how reliable ground water supplies will be. The Georgia Environmental Protection Division does not believe that ground water can be reliably, cost effectively developed as a major water source for many Piedmont cities and towns. The uncertainty over the quantity and cost of developing ground water is important because the Georgia Environmental Protection Division requires many new industries to locate where water resources can best serve their needs. The EPD's authority to issue permits for both water withdrawals (surface and ground) and wastewater discharge impacts directly on the siting of new industry in the state of Georgia. Thus, uncertainties over the availability of ground water can have important implications for the growth potential of Henry County.

B. Ground Water Management

The primary state agency concerned with ground water resources and management is the Environmental Protection Division (EPD) of the Georgia Department of Natural Resources (DNR). The geologic survey branch of EPD is the research and data gathering branch for Georgia's ground water resources. The EPD has the responsibility of regulation and enforcement of state and federal statutes to manage water use and to protect the quality of water resources. The Georgia system of having a single state agency (DNR) for environmental programs has facilitated water resource management within the state and enhanced intergovernmental cooperation among local, state, and federal agencies.

The institutional system for water resources centers on the use of a permitting system for management of water resources. The EPD has sole authority in issuing permits to water users for both surface and ground water withdrawals. This authority over ground water was granted to the EPD under the Ground Water Use Act of 1972, as amended in 1973. Permits are issued for ground water withdrawals in excess of 100,000 gpd. However, the major water consumer in the state, agriculture, is exempt; although in 1982 the law was amended to require agricultural uses over 100,000 gpd to report that use to EPD via their respective County Extension Agents. This exemption, along with the fact that large numbers of users withdrawing less than 100,000 gpd can add up to a significant quantity, means that overall ground water use management in Georgia is somewhat limited. Although agriculture is not a ground water user in Henry County at present, it could become so in the future. "An essential need is the inclusion of all significant water users into the management system" (Ledbetter 1980b, 34).

C. Ground Water Quality

Although ground water quality in the Piedmont is generally good, there are local areas where high concentrations of dissolved iron and other constituents occur naturally. There have been no reported ground water contamination incidents in Henry County and monitoring of drinking water as required by the Safe Drinking Water Act has not revealed any violations of standards (Fernstrom 1983).

Deep well injection of waste of any type has not been approved in the study area or in any part of the state. The potential for contamination of ground water is considered too great to allow for waste injection into the subsurface. The fractures may be linked and if the waste migrates, it could rule out a potential source of potable water. However, as is true throughout most of the nation, uncertainty exists about the potential for contamination from unknown, abandoned hazardous waste sites and from the illegal disposal of hazardous wastes by small generators (see Section 4.2).

Another future concern is the potential for ground water contamination from septic tanks (see Section 4.3). Because of the rural nature of the country, septic tanks are in widespread use and their number will increase if the county continues to experience large nonurban growth, as expected. A study of six counties by the Atlanta Regional Commission identified several problems with septic tanks and deficiencies in the regulatory programs (Atlanta Regional Commission 1981). Although Henry County was not included, three of the counties are adjacent to Henry County and thus their findings probably apply. Findings and recommendations include: (1) the most commonly mentioned problem and the one requiring the most attention is lack of owner maintenance; health departments should play a role in educating septic tank owners of maintenance needs and proper practices; (2) minimum allowable lot sizes range from

18,000-30,000 square feet; the State Department of Human Resources should consider adopting a region wide standard of 30,000 square feet; (3) about 40-50 percent of the region's land is considered unsuitable for septic tanks; septic tank failure areas were identified and should be used in identifying sewer expansion areas; and (4) there was an absence of a state management role in on-site wastewater disposal and state rules and regulations governing septic tanks were relatively weak.

3.6 SUMMARY OF CASE STUDIES

Each of the case study areas has experienced the diversified population, commercial and industrial growth that has been characteristic of the Southeast in general (Science and Public Policy 1981). However, each area is growing for different, although related, reasons: Columbia's is related to commercial and industrial development and growth of government employment; the coastal Georgetown to Wilmington area is a function of recreation and industrial use; the Miami area is experiencing growth in many service areas; and Henry County is experiencing both commercial development and sprawl from the Atlanta Metropolitan area. Growth rates in these areas have ranged between about 24 percent to 71 percent in the last decade, and similar growth is expected to continue during the coming decade.

This growth appears likely to intensify existing ground water management problems and potentially introduce new problems in the future. These problems and issues include inefficient utilization or overuse of available ground water, inadequate protection of ground water quality, and limited management of ground water resources. The following highlights some of the similarities and the differences found among the four areas. The key problem and issue findings have also been integrated into chapters 4 and 5, while the identification of policy options has been used to inform the analysis in chapters 6 through 9.

3.6.1 Ground Water Availability

Several conditions contribute to problems of ground water availability. Except for the Biscayne aquifer case, the local geohydrology of these areas is poorly known. This is especially true for Henry County where emphasis is placed on surface water to meet growing demands; yet, the 71 percent population increase in the last decade is intensifying competition for the Atlanta areas finite water resources. The limited knowledge of aquifer characteristics creates an uncertain role for ground water to help meet future needs and also complicates ground water quality management (as discussed below).

Increased population and high per capita water consumption are posing overdraft problems on a periodic basis in the coastal plain areas such as Georgetown/Wilmington. Drawdown occurs regularly in this area during the peak tourist season, which results in reduced well capacity and water shortages. Drawdown also occurs in the Biscayne aquifer in the summer dry season due both to increased use and reduced recharges, but problems there only become critical during periods of abnormally low rainfall.

For some communities, such as those in the Georgetown/ Wilmington area, poor well spacing (generally too close together) has created drawdown problems and well field size is inadequate to support further growth. Communities in these areas have only limited resources to develop new well fields. Because of these well spacing problems with existing fields, seasonal drawdown, overdraft, and the poor ground water quality (discussed below), communities in the Georgetown/Wilmington area (and other coastal areas) are looking to surface water supplies to meet their future needs.

3.6.2 Ground Water Quality

A wide range of current or potential ground water pollution sources are characteristic of the study sites, although there have been no documented cases of ground water contamination in Henry County. The most widespread and threatening are septic tank pollution, leaks from underground tanks and pipes, and landfills. Pollution from urban runoff is also widespread, but documented ground water contamination cases were not available. In addition, in South Florida, elevated nitrate levels can be associated with agricultural runoff. In Horry County (Georgetown/Wilmington case study) naturally high levels of floride and sodium have raised concerns about health impacts of water from the Black Creek Aquifer. The concerns have led Myrtle Beach to investigate the possible use of surface supplies as a substitute.

Pollution episodes continue to threaten recharge areas in three of the scenario locations: the Middendorf aquifer in the Columbia, South Carolina area; the water table in the Georgetown/Wilmington area; and the water table aquifer of Dade and Broward counties. In Henry County, the lack of knowledge about recharge mechanisms makes ground water quality protection difficult.

3.6.3 Management Problems and Issues

Management is constrained by limited data, divided responsibilities, and inadequate enforcement in most scenario locations. Geohydrologic data are poorest in the Piedmont area represented by Henry County and portions of the Columbia area of South Carolina. Division of responsibilites among supply and quality protection agencies limits management most in North Carolina and South Carolina. Perhaps south Florida has the most intensive management, but even here such problems as urban runoff, surburban sprawl, and corroding subsurface tanks and pipes lead to water quality problems, and the high rate of use for the large population leads to inadequate supplies during drought.

There are few, if any, controls on growth types and patterns in any of the scenario sites. In the coastal areas, current management problems are intensified by curtailed 208 programs and poorly coordinated programs that subsidize growth (such as provision of centralized water supplies) without concomitant environmental protection programs (such as sewer facilities). Land use planning is implemented to the greatest degree in Florida. However, in North and South Carolina and Georgia ground water quality over the long term could be adversely affected by inadequate controls at either the local or state levels on land uses, especially in areas of intensive ground water use or recharge.

3.6.4 Context of Current Ground Water Issues

For three of the case studies, ground water protection and management appear to be salient public policy issues. For Henry County, although ground water supplies about 47 percent of the total water used, few local public officials seemed concerned about its management.[1] The other case studies were characterized by public and administrative attention to contamination by a range of sources, including industrial and municipal landfills and chemicals from leaking tanks. Due to the geohydrology of the coastal areas, the mangement of use and protection of quality appear especially important.

The four states represented by these cases have made substantial progress over the past decade in passing laws and developing administrative programs to improve the management and protection of ground water resources. However, several management issues remain, including: (1) resolving problems of cooperation among water supply districts and utilities; (2) coordination and enforcing local, state, and federal functions; (3) removing gaps in the regulation of ground water pollution sources. For example, the extent of implementation of restrictive permit authority in North and South Carolina through existing capacity use laws is likely to be important in the coming decades. As another example, problems with hazardous waste management exist because of the absence of control over small generators of hazardous waste. Perhaps more importantly, with the exception of south Florida, the potential for development and implementation of long-term ground water protection plans appears to be constrained by limited information and resources and by an unwillingness to control land uses which can affect ground water. However, even in south Florida, water management objectives and priorities continue to be a source of conflict among the urban developers, agribusiness interests, environmentalists and the Water Management District.

---

[1] However, for Georgia as a whole, ground water has been an important public issue and the state has made substantial progress in developing a ground water management program. Major areas of concern include ground water use by agriculture in southwest Georgia and overdraft in the Savannah/Brunswick area.

REFERENCES

Allis, Sam. 1980. "North Carolina County Hit First in U.S. Legal Assult on Landfills." Wall Street Journal (June 24): 31.

Atlanta Regional Commission. 1976. Water Supply Plan for the Atlanta Region, Part I: Needs, Sources, and Policies. Atlanta, GA: Atlanta Regional Commission.

______. 1981. Atlanta Region Areawide Wastewater Management Plan--Executive Summary. Atlanta, GA: Atlanta Regional Commission.

Black, Crow, and Eidsness, Inc. 1977. Engineering Report 201 Facilities Plan for the West Horry County Region. June.

Broward County Environmental Quality Control Board. 1981. Results of Ground Water Quality Monitoring for 1979 and 1980 at Broward County's Solid Waste Disposal Facility, Davie, Florida. Fort Lauderdale, FL: Broward Co. Environmental Quality Control Board.

Broward County Planning Council. 1981. Potable Water Subelement of the Broward County Comprehensive Plan. Ft. Lauderdale, FL: Broward Co. Office of Planning.

Brunswick County Resources Development Commission. 1981. Brunswick County, North Carolina, Coastal Area Management Act Land Use Plan Update. Bolivia, NC.

Central Midlands Regional Planning Council. 1977. Land Resources Management Plan for the Year 2000. Columbia, SC: Central Midlands Regional Planning Council.

______. 1979. Columbia Metropolitan Water Quality Management Plan: Plan Summary. Columbia, SC: Central Midlands Regional Planning Council.

______. 1982. Metropolitan Columbia in the Year 2000: Facts and Issues Affecting Richland and Lexington Counties. Columbia, SC: Central Midlands Regional Planning Council.

Coastal Plains Regional Commission. 1979. Groundwater in the Coastal Plains Region: A Status Report and Handbook. Edited by the Interstate Groundwater Committee. Charleston, SC: The Commission.

Cressler, C. 1983. U.S. Geological Survey, Atlanta, GA. Personal communication.

Dade County Department of Environmental Resources Management. 1979. "Dade County '208' Areawide Water Quality Management Plan." February.

______. 1980a. "Protection of Potable Water Supply Wells Program." The Department, Dade County, FL, December.

______. 1980b. Volatile Organics Monitoring Program and Finalization of Herbicide Sampling, Open File Report. N.p.

Eakins, J. William, John Moran, et al. 1981. Drainage Report to New Hanover County Commissioners. Wilmington, NC: New Hanover County Board of County Commissioners.

Economic Development Commission. 1982. 1982 Industrial Directory: Richland and Lexington Counties. Columbia, SC: SMSA. Columbia, SC: Economic Development Commission.

Fenstrom, John. 1983. Georgia Department of Natural Resources, Environmental Protection Division. Personal communication, May 5.

Georgia Department of Industry and Trade. n.d. Economic Development Profile of Henry County. Atlanta: Georgia Dept. of Industry and Trade.

Howard, Victor. 1982. Broward County Environmental Quality Control Board. Personal communication, June 9.

Howells, David H. 1978. A Summary Report: Southeast Conference on Legal and Administrative Systems for Water Allocation and Management. Raleigh, NC: Water Resources Research Institute of the University of North Carolina.

______. 1981. "Comments on a National Groundwater Protection Strategy." Ground Water 19: 466-68.

Hull, J. E., and E. T. Wimberly. 1972. Hydrologic Conditions During 1971 in Dade County, Florida. Open File Report. U.S. Geological Survey.

Interstate Groundwater Committee, ed. 1979. Groundwater in the Coastal Plains Region: A Status Report and Handbook. Charleston, SC: Coastal Plains Regional Commission.

Klein, H., and J. E. Hull. 1978. Biscayne Aquifer, Southeast Florida. Water Resources Investigation 78-107. Tallahassee, FL: U.S. Geological Survey.

Klein, Howard, et al. 1975. Water and the South Florida Environment. Water Resources Investigation 24-75. N.p.: U.S. Geological Survey.

Kundell, James E. 1978. Ground Water Resources of Georgia. Athens: University of Georgia, Institute of Government.

Ledbetter, J. L. 1980a. "Developing Georgia's Coordinated Water Management Program--Surface, Ground, Quantity and Quality." Paper presented at United River Basin Management Symposium, American Water Resources Association, Gatlinburg, TN, May 5.

______. 1980b. "Georgia's Water Management." In Georgia Water Resources: Issues and Options, edited by James E. Kundell 31-34. Athens: University of Georgia, Institute of Government.

Lumpkin, Julie. 1982. "Water Ltd." South Carolina Wildlife (Spring): 45-49.

Mann, John. 1983. U.S. EPA Region IV, Atlanta, GA: Personal communication.

Mattraw, Harold C., John E. Hull, and Howard Klein. 1978. Ground-Water Quality Near the Northwest 58th Street Solid-Waste Disposal Facility, Dade County, Florida. Water-Resources Investigation 78-45. N.p.: U.S. Geological Survey.

Metropolitan Dade County Planning Department. 1979. Comprehensive Development Master Plan for Metropolitan Dade County. Miami, FL: Metropolitan Dade County Board of County Commissioners.

Moore, Gardner & Associates. N.d. On-Site Waste Water Treatment and Disposal Alternatives. Georgetown, SC: Waccamaw Regional Planning and Development Council.

______. 1979. Myrtle Beach Stormwater Study, Final Report: Data Interpretation and Analysis (Subtask D-3). Georgetown, SC: Waccamaw Regional Planning and Development Council.

Myrtle Beach, Chamber of Commerce. 1981. Myrtle Beach, SC: Mimeograph. September 17: 1-7.

Narkunas, James. 1980. Groundwater Evaluation in the Central Coastal Plain of North Carolina. Raleigh: North Carolina Dept. of Natural Resources and Community Development, Office of Water Resources.

North Carolina Department of Natural Resources and Community Development. 1978. Ground Water Conditions in the Flemington Area of New Hanover County with Emphasis on Effects of the Landfill. Report of investigation No. 16, Raleigh, N.C.: Environmental Management Division, North Carolina Department of Natural Resources and Community Development.

______. 1982. Personal communication from Rich Shiver.

O'Boyle, Peter, III. 1980. "Waste Treatment Firms Warned." The State, (November 20).

Putt, Larry O'Neill. 1981. "An Analysis and Evaluation of Water Rights in Alabama in Perspective with Other States in the South Atlantic and Gulf Region." Cumberland Law Review 12: 47-98.

Robertson, J. M. 1977. "The McIntosh Trail: Our Golden Triangle." Atlanta. Atlanta, GA: pp. 62-75.

Robison, T. M., and L. T. Mann, Jr. 1977. Public Water Supplies of North Carolina, Part 5: Southern Coastal Plain. Raleigh: Dept. of Natural Resources and Community Development.

Rook, J. J. 1975. "Formation and Occurrence of Chlorinated Organics in Drinking Water." Paper presented at the Ninety-fifth Annual Conference of American Water Works Association, Minneapolis, MN. June 8-13.

Science and Public Policy Program. 1981. "Southern Regional Environmental Assessment: Environmental Status Report" (draft) Science and Public Policy Program, University of Oklahoma.

Sherwood, C. B., H. J. McCoy, and C. F. Galliher. 1973. Water Resources of Broward County, Florida. Tallahassee, FL: U.S. Geological Survey.

South Carolina Budget and Control Board. 1981. South Carolina Statistical Abstract 1981. Columbia, SC: Division of Research and Statistical Services.

South Carolina Department of Health and Environmental Control. 1982. Inventory of Known Ground Water Contamination Cases and Generalized Delineation of Five Ground Water Recharge Areas in South Carolina. (Prepared by Hamit K. Hardee and Suzanna K. McFadden). Columbia: South Carolina, Department of Health and Environmental Control. Bureau of Water Supply and Special Programs. Ground Water Protection Division.

______. 1983. A Report to the General Assembly on Ground Water Contamination in South Carolina (by James M. Ferguson, Patrick A. Shirley, and Suzanna M. Workman). February.

______. Office of Environmental Control. Hydrology Division. N.d.(a) Evaluation of the Impact of Landfill Leachate on Ground-Water Quality at the Lexington County, South Carolina Landfill Site. Columbia: SC Dept. of Health and Environmental Control.

______. Hydrology Division. N.d.(b) "Water Resources of Lexington County, South Carolina: A Reconnaissance. By Donald A. Duncan and James M. Ferguson. N.p.

South Carolina Water Resources Commission. 1982. Personal communication with staff, Columbia, June.

South Carolina Wildlife Federation. 1981. Personal communication with staff, Columbia, June.

South Florida Water Management District. 1977a. Water Use and Supply Development Plan (draft). Vol. 3A. Lower East Coast Planning Area. West Palm Beach, FL: The District.

______. 1977b. Water Use and Supply Development Plan (draft). Vol. 1A: Physical Environment. West Palm Beach, FL: The District.

Spigner, B.C., K. Stevens, and W. C. Moser. 1977. Report on the Ground Water Resources of Horry and Georgetown Counties, South Carolina. Report No. 129. Columbia: South Caroline Water Resources Commission.

Swift, D. J., and S. D. Haron, Jr. 1969. "Stratigraphy of the Carolina Cretaceous." Southeastern Geology 10: 201-45.

Tarver, G. R. 1964. Hydrology of the Biscayne Aquifer in the Pompano Beach Area, Broward County, Florida. Report of Investigation 36. Tallahassee, FL: Geological Survey.

Thompson, Ralph B., ed. 1980. Florida Statistical Abstract, 1980. Gainesville: University of Florida, College of Business Administration, Bureau of Economic and Business Research.

U.S. Army Corps of Engineers. 1978. Metropolitan Atlanta Area Water Resources Management Study: Water Supply Study--Coweta, Fayette, Henry, and Spalding Counties, Savannah, GA: U.S. Army Corps of Engineers, September.

U.S. Department of Agriculture. Soil Conservation Service. 1976. Soil Survey of Lexington County, South Carolina. In cooperation with S.C. Agricultural Experiment Station and S.C. Land Resources Commission. N.p.

______. 1978. Soil Survey of Richland County, South Carolina. In cooperation with S.C. Agricultural Experiment Station and S.C. Land Resources Commission. N.p.

U.S. Department of Commerce. Bureau of Economic Analysis. 1980. Regional Economic Projections. Washington DC: U.S. Bureau of Economic Analysis.

______. 1981. 1980 OBERS, BEA Regional Projections: Economic Activity in the United States, Vol. 8, Region 5, Southeast. Washington, DC: Government Printing Office.

U.S. Department of the Interior. Geological Survey, Water Resources Division, South Carolina Division. 1981. Water Resources Data for South Carolina, Water-Data Report SC-80-1. Columbia, SC: U.S. Geological Survey.

U.S. Environmental Protection Agency. 1980. Proposed Groundwater Protection Strategy. Washington, DC: Environmental Protection Agency.

U.S. Geological Survey. South Carolina Division. 1982. Personal communication with staff, Columbia, South Carolina.

______. 1982. Personal communication with staff, Water Resources Office, Division Myrtle Beach.

Waccamaw Regional Planning and Development Council. 1976. Land Use Plan: Horry County, South Carolina. Conway, SC: Horry County Planning Commission.

______. 1977. Waccamaw Regional Land Use Plan. Georgetown, SC: Waccamaw Regional Planning and Development Council.

______. 1981. The Horry County Story. Conway, SC: Horry County Development Board.

Walker, Tom. 1982. Broward County Planning Council. Personal communication.

Wilmington-New Hanover Planning Department. 1980. Analysis of Existing Land Use. Technical Report no. 8. Wilmington, NC: Wilmington-New Hanover Comprehensive Planning Program.

Zack, Allen L. 1977. The Occurrence, Availability, and Chemical Quality of Ground Water, Grand Strand Area and Surrounding Parts of Horry and Georgetown Counties, South Carolina. Report no. 8. Columbia: South Carolina Water Resources Commission.

______. 1980. Geochemistry of Fluoride in the Black Creek Aquifer System of Horry and Georgetown Counties--and Its Physiological Implications. Geological Survey Water Supply Paper 2067. Washington, DC: Government Printing Office.

CHAPTER 4

GROUND WATER QUALITY PROBLEMS AND ISSUES

4.1 INTRODUCTION

The availability of surface and ground water is intimately related to its quality. This is especially the case for ground water since it supplies such a large percentage of drinking water. Yet no comprehensive national program for protecting ground water quality comparable to that for surface water exists. It is ironic that many of the surface water protection programs developed to comply with the Clean Water Act (CWA) have increased threats to ground water by diverting pollutants to land. The limited public concern for ground water protection probably can be explained by the low visibility of ground water quality degradation. Only in the last decade when highly publicized pollution incidents such as Love Canal occurred did ground water pollution emerge as a prominent public policy issue. This is reflected in the passage of the Safe Drinking Water (SDWA) Act in 1974, the Resources Conservation and Recovery Act (RCRA) in 1976, and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) in 1980.

Water pollution trends and issues were reviewed in Chapter 2, primarily focusing on surface water. Because of the hydrologic connection between surface and ground waters, activities that pollute surface water represent potential threats to ground water as well. However, certain types of activities represent more of a threat to ground water quality than do others, particularly land disposal of hazardous wastes, industrial discharges, septic tanks, oil and gas drilling, and deep well injection of wastes. Several characteristics of ground water are important to understanding ground water pollution as contrasted to surface water pollution:

- Due to the slow movement of ground water and the much slower microbial degradation processes to break down pollutants, once ground water is polluted it generally takes very long periods of time (hundreds of years or longer) for the problems to disappear. This is in strong contrast to surface waters where once polluting activities are stopped, natural conditions may be restored in months or a few years;

- Cleaning up contaminated aquifers is technically difficult and very expensive--usually prohibitively so. This means that, practically speaking, ground water pollution is often an irreversible process;

- Ground water pollution is a latent problem because degradation may not appear until many years after the polluting activity is initiated. Two factors contribute to this: (a) lack of mixing in aquifers creates "fronts" of polluted ground water which may take a long period of time to reach an active well and be detected; and (b) pollutants deposited on the land may take years to leach into underlying aquifers;

- Ground water quality degradation is not visible;

- Because ground water is usually of higher quality than surface water, it serves as a major source of drinking water, often with little or no treatment; and

- The costs of monitoring ground water quality are much higher than for surface water. This is due to: (a) the high cost of drilling monitoring wells; and (b) the slow flow aquifers which require taking many samples throughout the aquifer to obtain an accurate picture of ground water quality conditions.

This chapter addresses five categories of ground water quality problems. Section 4.2 analyzes hazardous waste management, the most important point source threat to ground water. Nonpoint sources of pollution and associated land use issues are discussed in Section 4.3, and two nonpoint sources--septic tanks and energy/mineral production--are dealt with in more detail. Problems associated with ground water data and information systems are covered in Section 4.4. Section 4.5 addresses drinking water quality issues. Institutional and management issues of ground water protection, including legal regulatory gaps and deficiencies in administrative capacity, are addressed in Section 4.6. The final section of this chapter (4.7) summarizes the major findings and conclusions.

4.2 HAZARDOUS WASTE DISPOSAL

Summary: Hazardous waste disposal has in the past, led to numerous incidents of ground water pollution in the Southeast. This region generates about 25 percent of the hazardous waste in the U.S., mainly because of the concentration of the chemical industry The passage of RCRA and the participation of state and local authorities in its enforcement should reduce the probabilities of ground water pollution occurring from hazardous waste. However, several problems with respect to hazardous waste management remain, including:

- The difficulty of enforcing stringent regulations for the large numbers of existing on-site facilities;

- The need to establish new sites for hazardous waste management facilities;

- The need for policies to deal with small hazardous waste generators who are excluded from RCRA regulations;

- The need to maintain the momentum acquired so far in the implementation of RCRA and the establishment of the hazardous waste management industry;

- The need to enforce the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (superfund) legislation quickly and effectively and to extend its authority over more years;

- The need to detect old, closed hazardous waste disposal sites and assess the risks for ground water pollution which may result from them. The application of "Superfund" legislation in cleaning up old dumping sites is all important; and

- The need for a shift from land disposal to solvent recovery, recycling, chemical treatment and incineration.

4.2.1 Introduction

The Southeast is among the larger generators of hazardous waste, accounting for approximately 25 percent of the U.S. total (Booz, Allen & Hamilton, and Putnam, Hayes & Bartlett 1980). This is largely due to the fact that this region houses a substantial capacity of the U.S. chemical industry and considerable capacity of other hazardous waste producing sectors such as primary metals, fabricated metal products, textiles, pulp and paper, and stone, clay, and glass products. Table 4-1 presents 1980 figures of industrial hazardous waste generation by industry for Region 4 and the U.S., and Table 4-2 presents 1972 data of hazardous waste generation by industry and for each state of the Southeast. There are wide discrepancies in comparing corresponding figures between the two tables. Hence, the data might best be interpreted as indicative of general trends. More accurate data on hazardous waste generation will take some time to appear as they will largely derive from the enforcement of RCRA. For example, one of the best studies to date in developing hazardous waste generation data is by the California Toxic Waste Assessment Group (1981), which is based

TABLE 4-1: 1980 INDUSTRIAL HAZARDOUS WASTE GENERATION BY INDUSTRY

(thousands of wet metric tons)

Industry (SIC)	U.S. Total	Southeast
Textile Mill Products (22)	203	132
Lumber & Wood Products (24)	87	20
Furniture & Fixtures (25)	36	9
Paper & Allied Products (26)	1,295	156
Printing & Publishing (27)	154	19
Chemicals & Allied Products (28)	25,509	8,763
Industrial Inorganic Chemicals	8,072	5,723
Plastics Materials, Synthetics	769	192
Drugs	106	8
Other Chemicals	3,364	688
Paints and Allied Products	125	20
Industrial Organic Chems. and Agric. Chems., N.E.C.	13,066	2,130
Explosives	7	2
Petroleum & Coal Products (29)	2,119	90
Petroleum Refining	1,901	57
Petroleum Re-refining	218	33
Rubber and Misc. Plastics (30)	249	39
Leather & Leather Tanning (31)	474	14
Stone, Clay, & Glass Production (32)	17	3
Primary Metal Industries (33)	4,061	434
Ferrous Metals	2,330	163
Nonferrous Metals	1,731	271
Fabricated Metal Products (34)	1,997	172
Machinery, Except Electrical (35)	322	29
Electric & Electronic Equip. (36)	1,093	82
Electric, Electronic Equipment	609	77
Batteries	484	5
Transportation Equipment (37)	1,240	106
Instruments & Related Products (38)	90	6
Miscellaneous Manufacturing Industries (39)	318	42
Nonmanufacturing Industries	1,971	237
TOTAL	41,235	10,353

Source: Booz, Allen & Hamilton and Putnam, Hayes & Bartlett 1980.

TABLE 4-2: HAZARDOUS WASTES GENERATED BY INDUSTRIES GROUPED BY STANDARD INDUSTRIAL CLASSIFICATION BY STATE--1972 (thousands of metric tons per year)

Industry (SIC)	AL	FL	GA	KY	MS	NC	SC	TN
Food & Kindred Products (20)	3.5	6.6	6.6	3.1	2.5	5.6	1.7	5.1
Textile Mill Products (22)	19.8	2.2	47.4	3.0	3.4	116.2	62.7	12.5
Apparel & Other Textile Products (23)	5.5	3.4	7.6	2.9	4.1	7.8	4.8	7.2
Lumber & Wood Products (24)	22.8	15.0	28.2	12.4	22.5	32.5	14.6	15.1
Furniture & Fixtures (25)	0.3	0.6	0.5	0.3	0.9	4.8	0.3	1.6
Paper & Allied Products (26)	22.6	18.8	30.5	8.9	7.2	6.2	15.4	19.2
Printing & Publishing (27)	0.7	2.7	1.4	1.2	0.4	1.6	0.5	2.3
Chemicals & Allied Products (28)	401.2	859.1	526.1	533.6	211.9	1,177.0	1,033.2	1,097.4
Petroleum & Coal Products (29)	4.4	4.4	7.4	7.9	6.4	3.9	1.5	3.9
Rubber & Misc. Plastics Products (30)	2.1	1.6	2.0	0.9	0.8	2.6	1.5	2.4
Leather & Leather Products (31)	2.7	1.4	1.2	1.9	0.8	1.4	0.1	7.0
Stone, Clay & Glass Products (32)	37.1	60.6	67.2	33.0	31.7	63.9	40.4	68.0
Primary Metal Products (33)	61.6	4.6	16.2	25.2	3.4	9.6	6.9	24.9
Fabricated Metal Products (34)	37.5	38.7	27.9	30.6	12.0	32.3	13.4	46.3
Machinery, except Electrical (35)	2.9	4.5	3.4	9.2	2.3	7.7	5.1	6.2
Electric & Electronic Equipment (36)	1.8	5.4	2.1	4.3	2.4	5.2	2.4	4.7
Transportation Equipment (37)	6.4	10.3	8.9	4.4	10.0	3.1	1.5	6.6
Instruments & Related Products (38)	0.1	0.3	0.2	0.2	0.1	2.4	1.3	1.0
Misc. Manufacturing Industries (39)	0.9	2.1	6.2	1.2	1.1	1.9	1.5	3.8
Total	633.9	1,042.3	791.0	684.2	323.9	1,485.7	1,208.8	1,335.2

Source: Copenhaver, Olsen, and Rice 1978, 374-75.

on an analysis of manifest data from hazardous waste haulers and hazardous waste management facilities. Many of the studies carried out under contract for state agencies (e.g., North Carolina Dept. of Human Resources 1978; Weston 1978; Environmental Dynamics 1979) acknowledge the lack of data and the difficulty of obtaining them from industry and arrive at their conclusions by the adoption of generalizations based on limited data.

Furthermore, the geographical location of a hazardous waste generator determines the geographical location of disposal only when it is disposed on site. As long as there is a shortage of commercial hazardous waste management facilities, hazardous waste may have to be hauled long distances. Thus, both disposal capacity and hazardous waste generation are the determining factors of how much hazardous waste is treated within a geographical area. Available hazardous waste management capacity also determines to some extent the cost of treatment and disposal, and the quantity of hazardous waste which is disposed illegally.

Hazards resulting from the unsafe dumping of toxic wastes are numerous. The Environmental Impact Statement for RCRA describes a selected set of 300 accidents from across the U.S. which have resulted from bad management of hazardous wastes (U.S. EPA, Office of Water and Waste Management 1979). Of these, 125 led to underground water pollution, affecting, in some cases, hundreds of wells.

Ground water contamination from hazardous waste can occur from:

- Disposal on land (landfills or lagoons);
- Spills resulting from storage leaks and transportation accidents;
- Deep well injection; and
- Illegal disposal of hazardous waste in municipal sewers or on land.

Current federal legislation affecting hazardous waste disposal (RCRA, TSCA, CWA, SDWA, CERCLA) goes a long way towards providing the legislative framework for regulating hazardous waste management activities. A crucial question is the extent to which these regulations will be enforced by EPA, state, and local authorities.

4.2.2 Sources and Trends

Based on a review of available reports and telephone interviews with state officials in each of the eight states, this section summarizes the situation for hazardous waste management for the southeastern states, including specific state policies for hazardous waste management which have been adopted or proposed.[1]

Table 4-3 presents for each southeastern state (a) the major industrial hazardous waste generators in terms of SIC classification; (b) the major hazardous waste streams; (c) the numbers of hazardous waste management facilities in terms of whether they are private (on-site) or commercial (off-site) and in terms of technology used: incinerators, chemical treatment, land disposal, solvent recovery, etc.; and lastly (d) the overall balance of import/export of hazardous waste.

A. Hazardous Waste Generation

The chemical industry is the prominent generator of hazardous waste in all eight states. It is particularly so in North Carolina, South Carolina, and Tennessee.

Major hazardous streams are more diverse when compared to the number of generating industries. This diversity stems from a number of causes; for example:

- The location of particular sectors of the chemical industry, e.g., titanium dioxide in Mississippi;
- The relative importance of small generators of hazardous waste, e.g., electroplating effluents and asphalt residues in Florida;
- The large commercial hazardous waste management facilities in Alabama and South Carolina which import hazardous waste from other regions and states; and
- The diversity of products of the chemical industry.

In terms of the number of hazardous waste management facilities given interim status under RCRA regulations, their distribution among the states and between on-site and off-site (commercial) facilities is as follows:

---

[1] Appendix A to this section lists the individuals contacted.

TABLE 4-3: HAZARDOUS WASTE MANAGEMENT CHARACTERISTICS FOR THE SOUTHEAST

State	Major Hazardous Waste Generating Industries[a] (weight)[b]	Major Hazardous Waste Streams	Hazardous Waste Management Facilities	Importer or Exporter of Hazardous Wastes
Alabama	Chemicals (401) Primary Metals (62) Fabricated Metals (38)	Very hazardous chemicals including PCBs, insecticides, chlorinated hydrocarbons	On-Site: 240 including 4 incinerators, 2 deep well injection Off-Site: 1 large hazardous waste management facility comprising: 1 landfill, 2 solvent recovery units, 2 incinerators, 1 incinerator ship	Overall importer
Florida	Chemicals (860) Stone, Clay and Glass (61) Fabricated Metals (40)	Electroplating effluents, asphalt residues, acid solutions with heavy metals, halogenated and other organic solvents	On-Site: 305 Off-Site: ?, incinerators, recycling facilities	Overall exporter (to South Carolina, Alabama, Georgia)
Georgia	Chemicals (526) Stone, Clay and Glass (67) Textiles (47) Lumber, Wood (28)		On-Site: 332 Off-Site: 1 incinerator	Overall exporter (to South Carolina, Alabama)
Kentucky	Chemicals (534) Stone, Clay and Glass (33) Primary and Fabricated Metals (56) Oil Refining (8)	Paint sludge, solvents, tetraethyl lead sludge, halogenated solvents with metals, lime sludge, acid solutions with metals, organic solvents	On-Site: 228 Off-Site: 6 4 solvent recovery, 2 incinerators	Balanced
Mississippi	Chemicals (212) Stone, Clay and Glass (32) Lumber, Wood (22)	Clay absorbents, aqueous acid solutions, titanium dioxide	On-Site: 157 Off-Site: 1 1 land farming	Overall exporter (to Louisiana, Texas, South Carolina, Alabama, Arkansas, Illinois)
North Carolina	Chemicals (1,180) Textiles (116)	Pesticide residues, heavy metal sludge, acid solutions with heavy metals, spent liquors from dyeing textiles, Synthetic fiber residues	On-Site: 408 Off-Site: 6 including 2 incinerators and 4 solvent recovery units	Overall exporter (to South Carolina, Alabama)

(continued)

TABLE 4-3: (continued)

State	Major Hazardous Waste Generating Industries[a] (weight)[b]	Major Hazardous Waste Streams	Hazardous Waste Management Facilities	Importer or Exporter of Hazardous Wastes
South Carolina	Chemicals (1,030) Textiles (63) Clay and Glass (40)	Pesticide residues, plating, metal finishing sludges, alkali heavy metal solutions, dyestuff residue liquors, halogenated solvents	On-Site: 204 Off-Site: 4 including 1 landfill, 1 incinerator, and 2 chemical treatment	Overall importer
Tennessee	Chemicals (1,100) Primary Metals (25) Fabricated Metals (46) Stone, Clay and Glass (68)	Aqueous acids with metals, alkali solutions with heavy metals, heavy metal sludge, halogenated solvents, pesticides, organic solvents	On-Site: 150 including 4 deep wells Off-Site: 13 including 2 chemical treatment, 4 storage, 7 recovery and recycling	Overall exporter (to Alabama)

[a] Chemicals (SIC 28), Primary Metals (SIC 33), Fabricated Metals (SIC 34), Stone, Clay and Glass (SIC 32). Textiles (SIC 22).

[b] Thousands of tons per year.

	On-site	Off-site
Alabama	260	1
Florida	305	?
Georgia	332	1
Kentucky	228	6
Mississippi	157	1
North Carolina	408	6
South Carolina	204	4
Tennessee	150	13
Total	2,044	32

The commercial (off-site) facilities use the following technologies:

	Total	Landfill	Solvent Recovery	Chemical Treatment	Incinerator	Land Farm	Ship	Storage
Alabama[a]	1	1	2		2		1	
Florida	?							
Georgia	1				1			
Kentucky	6		4		2			
Mississippi	1					1		
North Carolina	6		4		2			
South Carolina	4	1		2	1			
Tennessee	13		7	2				4
Total	32	2	17	4	8	1	1	4

[a] One company owns a site which includes a landfill, two solvent recovery units, and two incinerators. This company operates the only incinerator ship in the U.S.

Clearly, the most widely used technologies in off-site facilities are solvent recovery and incineration. However, data on the volumes of hazardous waste processed by each type of facility are not yet available.

B. Ground Water Pollution Incidents

A large number of the documented damage cases from hazardous waste land disposal have involved ground water contamination (Federal Register 1982a). All states of the Southeast have reported incidents of ground water pollution from hazardous waste disposal.

The number of incidents and their severity varies widely among states. Florida reported a large number of such incidents resulting from its particularly shallow water table. One of these sites is being cleaned up with "Superfund" support. Kentucky, Tennessee, and South Carolina and North Carolina have reported serious support from the "Superfund" has been solicited. These southeastern states have received funds from their application for "Superfund" support. In addition, all the southeastern states have received "Superfund" contract support from EPA regional headquarters (Mason 1983).

C. State Policies to Discourage Land Disposal

Most of the states of the Southeast have not limited their legislative activity in the implementation of RCRA, but have passed or are in the process of passing state legislation designed to cope with particular aspects of the hazardous waste disposal issue. From the measures reported by the states, it appears that two general approaches have been adopted: incentives to reduce disposal of hazardous waste on land, and incentives for local authorities to accept hazardous waste management facilities.

Kentucky and Florida have passed and South Carolina attempted to pass legislation which imposes taxes on hazardous waste generators who dispose their waste on land, while reducing or completely eliminating such taxes for those generators who treat or recycle their waste.

Along the second line, Kentucky, Mississippi, and Alabama have passed legislation which allows local authorities to impose special taxes on hazardous waste management facilities which operate in their area. The income from such taxes helps to improve the cost/benefit equation for local authorities which house hazardous waste management facilities.

Alabama and Mississippi have also established hazardous waste management facility funds to provide local authorities which permit the installation of a hazardous waste management facility with the necessary finances for building roads, railway tracks, and often other infrastructure items.

The state of Georgia attempted to acquire a site, build a hazardous waste management facility, and then offer it to a contractor to operate. This effort, which was part of the industrialization policy of that state, did not succeed because of the opposition of the local public.

Lastly, Kentucky passed legislation exempting from state taxes investments by industry in pollution control equipment.

4.2.3 Problems and Issues

A. Availability and Siting of Hazardous Waste Management Facilities

A recent EPA study (Booz, Allen & Hamilton and Putnam, Hayes & Bartlett 1980), estimated that the Southeast had, in 1981, a surplus of 210,000 wet metric tons per year in off-site capacity. Such figures, however, can only be considered as an indication of hazardous waste management facility availability within a geographic area. The extensive transport of hazardous waste that takes place across the U.S. from generators to disposal and treatment facilities coupled with the overall shortage of hazardous waste management facilities, particularly in the East and Northeast, ensure that most available off-site capacity will be used.

By far the larger number of hazardous waste management facilities are on-site. Most state authorities contacted indicated that these facilities were not monitored in the past with respect to ground water contamination, but following the passage of RCRA, measures are being taken to put in place the necessary installations (monitoring wells, etc.) for this purpose. This seems to be a rather slow process, and a large number of such facilities will not be monitored in the near future. Given the fact that most on-site facilities were operating before RCRA, there is no doubt that some of them will need to discontinue their operations if the risks of ground water contamination are to be minimized.

Over the longer term, implementation of strict hazardous waste disposal regulations may lead to three types of development which affect the availability of hazardous waste management facilities:

- Large generators of hazardous waste will upgrade their current on-site facilities to comply with regulations and avoid paying the extra costs of transport and fees of the hazardous waste management industry. They will also work toward using raw materials and processes which generate less hazardous waste;
- Small generators of hazardous waste will close down their on-site facilities which do not meet the standards, or those which may lead to costly court action brought by objecting parties. They will turn to the hazardous waste management industry for transport and disposal of waste or dispose their wastes illegally; and
- The hazardous waste management industry will establish large facilities to accommodate the demand for its services. To identify the necessary new sites, a close cooperation between state and local authorities and the industry will probably be required.

Furthermore, there is a trend towards increasing recycling, resource recovery, incineration, and decreasing land disposal. This trend is encouraged: (a) by the implementation of RCRA; (b) by the shortage of landfill capacity and, therefore, by the increasing cost of land disposal; (c) by some state governments which add to the cost of land disposal by imposing state taxes on the generators; and (d) by public opposition to land disposal. All these factors will enhance the building of more incinerators, solvent recovery installations, etc., as opposed to landfills and lagoons. Thus it seems that, in the long run, the above factors will lead to more ground water protection by limiting the number of land disposal facilities.

For the immediate future, however, the shortage of hazardous waste management facilities and, in particular, of land disposal facilities, which at present are the cheapest way of disposal, leads to two possible hazards for ground water contamination: (a) it increases the average mileage between the generator of hazardous waste and the disposal facility, thus raising the cost of disposal and increasing the probability of traffic accidents and spills along the highways and railways; and (b) due to a lack of competition, it allows the hazardous waste management industry to charge high prices for its services, thus encouraging small hazardous waste generators to dispose such waste illegally--dumping it in municipal sewers or by the roadside--and thus posing a direct and difficult to control threat to ground water quality.

The price that hazardous waste management companies charge for transport ranges from $2.00 to $4.00 per loaded truck (18 tons) mile. At a price of $3.00 per mile and for a distance of 200 miles, the cost of transporting a truck load will be $600. Hazardous waste management companies charge between $40 and $70 per cubic yard for land disposal. Assuming an average price of $55 per cubic yard, the disposal of a truck load will cost about $900. Thus, transport costs are about 40 percent of the total expenditure; or, put in another way, a hazardous waste generator near a facility spends 40 percent less for disposal than another generator which is located 200 miles away. The cost of incineration or solvent recovery is $300 to $400 per ton of treated wastes, so that transport costs--following the above assumptions--are only about 8 percent of the total costs.

The siting of new hazardous waste management facilities is a critical issue for the protection of ground water. Siting is also the most thorny issue when public acceptance is considered. Public opposition however, is related only partly to ground water contamination and the risk of adverse health effects from the consumption of this water. Aesthetics, land value, transport, noise nuisance, concern over disagreeable smell, sponsor and regulatory agency credibility, quality of wastes to be disposed, and a diversity of economic issues such as lack of compensation for the nuisances or losses to agriculture and other competitive uses of the land are the other factors which cause the public to object to siting such facilities (U.S. EPA, Office of Water and Waste Management 1979). RCRA establishes guidelines and procedures which, if followed, greatly reduce the probability of ground water contamination. The major effect of public opposition is limiting the available capacity for disposal on land and thereby increasing the price charged to generators for land disposal. On the one hand, this enhances the shift to treatment, recycling, and incineration, and consequently the probability for ground water contamination decreases. On the other hand, ground water pollution may result from the increased transport, the probability of illegal disposal, and the continuing use of existing on-site facilities which do not meet stringent standards, but which they have to operate because of the lack of a new site.

Most southeastern states have tried to create special procedures for siting objectionable facilities (Yang 1981). These procedures can be classified in three groups, depending on which authority has the major say in the decision:

(1) Local authorities have the final say in zoning under existing state laws. Alabama and South Carolina belong to this class of states;

(2) State legislatures have some degree of preemptive authority over local government in overriding local laws and regulations restricting the siting of hazardous waste management facilities. The degree of that authority varies from complete state control over all decisions of local authorities (North Carolina), to limited preemptive control in special instances. For example, in Florida the state's Department of Natural Resources and the Regional Planning Council may approve deviations from local zoning for the siting of a hazardous waste management facility if it fulfills specific environmental, economic, and technical criteria. Georgia's Department of Natural Resources has preemptive authority over all local decisions, with the exception of local zoning ordinances. Mississippi's Department of Health is granted preemptive authority over a local ordinance if the proposed site is within an industrial zone; and

(3) State boards offer a third option for siting hazardous waste management facilities. The preemptive rights of state governments over local authorities have come into question by the public and, in some cases, the dispute has been taken to the courts. Establishing state boards for siting hazardous waste management facilities is an intermediate solution which seems to offer some advantages in reducing polarization between state and local

authorities. Tennessee established such a board, consisting of persons with technical expertise in agriculture, geology, and engineering; representatives from generating industries and environmental and local interest groups; ex-offico members from the departments of Public Health, State Planning, and Economic and Community Development. The board mandate includes the development of a hazardous waste management plan for the state. Its permitting authority is limited to off-site facilities. Siting boards may have a positive impact on the supply of facilities because they provide a mechanism for local input into the siting process. Georgia and Alabama have considered establishing similar boards.

In most cases states have not been successful in implementing proposed policies to facilitate the development of hazardous waste management facilities. It may be a coincidence, but the only two states--Alabama and South Carolina--in the Southeast which have surplus waste management capacity and treat a large part of the hazardous waste produced in neighboring states have assigned the final responsibility for zoning to the local authorities. North Carolina, Florida, Georgia, and Mississippi have given state agencies some degree of preemptive authority over local government in siting decisions. None of them have off-site landfills and all are net exporters of hazardous waste. An important initiative is that of Georgia which has considered the establishment of a hazardous waste management facilities as a business opportunity for the state; however, it has not succeeded to date due to public opposition. The relative success of Alabama and South Carolina and the recent legislation in Mississippi may indicate the emerging trend of putting local authorities in the delicate position of balancing the cost/benefit equation, while the state helps to enhance these economic benefits. As long as the state applies the RCRA directives rigorously, this approach may prove to be a good policy for providing the needed hazardous waste management capacity.

Lately, there is strong interest on the part of the hazardous waste management industry to invest in incineration ships. Given the lengthy coastline of the Southeast, this may be a good solution, but it will reduce only partially the hazards for ground water pollution because only a portion of the total volume of hazardous wastes may be treated in this way (flammable liquids and solids). Furthermore, technical problems like storage of hazardous waste at ports and concerns over the pollution by toxic chemicals in case of navigational accidents are likely to remain a continuing concern.

B. Incentives for the Development of the Hazardous Waste Management Industry

The demand for hazardous waste management services and the potential profits involved provide a strong incentive for the hazardous waste management industry to expand in terms of number of companies, geographic spread, and capacity of facilities. This expansion, however, depends on two factors:

- The federal government's enforcement of legislation regulating hazardous waste management; and
- Availability of sites for hazardous waste management facilities.

Given the importance of these two factors, they are treated in some detail in other sections. In this section, the focus is on the role state and local governments play in encouraging the expansion of the hazardous waste management industry.

Information obtained from state authorities provides strong confirmation of the proposition that market forces and federal legislation will enhance the expansion of the hazardous waste management industry and, in particular, the establishment of chemical treatment, resource recovery, and incineration facilities. Assuming enforcement of RCRA, the number of on-site landfills and lagoons will be reduced. Most states have begun monitoring ground water quality in some (but not all) such sites and it is likely that some facilities will be found inadequate with respect to RCRA standards. These generators of hazardous waste have not much flexibility in resiting their on-site disposal facilities, and hence they will need to turn towards the hazardous waste management industry.

In some states of Region 4, state authorities consider the hazardous waste management industry as a new service industry which may be accommodated to the economic benefit of the state both as a service to manufacturing companies which will move into the state and also as an income-generating industry serving out-of-state hazardous waste generators as well. For example, as described earlier, the State of Georgia attempted to develop a hazardous waste management facility and offer it to interested contractors, although this attempt has been frustrated so far by public opposition. The state of South Carolina owns a site for low level nuclear waste disposal which is operated under contract by a licensee.

Mississippi has passed legislation allowing local authorities to levy a tax of $5.00 per ton and $2.00 per barrel of hazardous waste disposed in a management facility operating within their jurisdictional boundaries, with 70 percent of the revenue staying with the local authority. The same legislation provides local authorities with low interest loans from a special state fund to construct the necessary infrastructure (access roads, railway tracks, etc.) for the operation of hazardous waste management facilities. Alabama has also levied a tax on incoming hazardous waste for treatment and/or disposal, with the primary beneficiary being the local authority which houses the management facilities. It receives 95 percent of the total tax income.

Other states of the Southeast have not provided any special measures--tax or otherwise--for the development of the hazardous waste management industry. With the exception of South Carolina and Kentucky they are all net exporters of hazardous waste. At issue is whether the other states should undertake some special efforts to help ensure adequate capacity for the hazardous waste management industry in the Southeast.

Lastly, a barrier to the expansion of incineration, recycling, and chemical treatment capacities may prove to be the high price that the industry is charging for these services. The $400 charge for the incineration of one ton of hazardous waste is certainly a high price, and an incentive for continuing the practice of land disposal. It has been reported in the press that some of the installed capacity for incineration is not being used. If there is such a trend, then return of investment for incinerators will be more slow to come.

C. Implementation of Legislation and Regulation

The lack of legislation prescribing ground water standards makes the regulation and monitoring for ground water more difficult compared to surface waters (Tripp and Jaffe 1979). However, with respect to ground water protection from hazardous waste management facilities, RCRA, TSCA, and SDWA provide guidelines for ensuring that minimal adverse impacts occur. Although the development of regulations and standards under RCRA has taken several years longer than intended in the legislation, there are several indications that improvements in the protection of ground water are occurring:

- Most southeastern states have carried out a qualitative and quantitative evaluation of hazardous waste streams. As mentioned earlier, these evaluations were not comprehensive, but it is expected that they will be improved as more data become available;
- The applications for interim status have provided concrete information as to the number, locality, waste characteristics, etc. of existing on-site and off-site hazardous waste management facilities;
- The manifest system for the transport of hazardous waste has given substantial information to state authorities

as to where the hazardous waste is produced and where it is treated and/or disposed;

- The RCRA regulations for ground water protection have now been issued by EPA and are in the process of being enforced, particularly in existing off-site hazardous waste management facilities, by putting in place the necessary monitoring wells and collecting the prescribed data. However, on-site facilities provide a much greater problem due to the large numbers involved;
- Waste generators were brought in the position to understand whether their on-site facilities will be able to operate under RCRA regulations or not, and they have opted accordingly for better suited methods of disposal. Resource recovery, recycling, treatment and incineration have come to be more accepted for the future under RCRA;
- Some states, acknowledging the risk of ground water pollution from landfills and lagoons and the public opposition to siting new hazardous waste management facilities, have passed tax legislation which penalizes generators who dispose their hazardous waste untreated as compared to those who neutralize it on site; and
- The hazardous waste management industry has been encouraged by the evidence that EPA and the states were enforcing RCRA and by the increasing demand for their services by the manufacturing industry. Hence, they were able to raise the capital to invest in new plants. Given the public opposition to landfills, they have raised the prices on land disposal and built incinerators, and solvent and other resource recovery installations.

All these activities point to a situation where, given time, ground water pollution from hazardous waste will be reduced. RCRA enforcement will not occur overnight; in the interim period, ground water pollution accidents should be expected to continue to occur. It is very important, therefore, that this interim period be kept as short as is possible. EPA measures taken in 1981 showed a tendency towards slowing down or even reversing the earlier trend of RCRA enforcement (e.g., permitting land disposal of liquid hazardous waste in drums). The reaction of Congress, the public, and the hazardous waste management industry to this attitude influenced the EPA in its more recent policies. Congress, for example, demanded that EPA come up with its interim-final regulations before the end of July 1982. The hazardous waste management industry objected to EPA's decision to allow temporary disposal of hazardous liquids in barrels, because such a measure would have delayed the return on the industry's investment in incinerators, recycling, and chemical treatment plants. The public affected by the old neighborhood dumping sites has exerted pressure on EPA through its representatives and the press.

Recent EPA measures relative to RCRA enforcement have been generally well received by the states, local authorities, environmentalists, and industry, particularly for existing facilities. However, some have expressed the view that the regulations affecting existing on-site facilities are "fairly weak" (Sun 1982). EPA policy in the next four to five years with respect to RCRA enforcement will be crucial in determining the extent to which ground water is threatened by hazardous waste.

The following are areas where existing legislation seems to allow for loopholes which may lead to pollution of ground water:

(1) Identification of Sites

Operators of existing sites (private or commercial) who wished to continue their operations have asked--and obtained--interim status. These sites have to comply with the EPA interim-final directives after February 1983 or must discontinue their operations.

Operators who did not seek interim status may have abandoned their sites, or they may continue to operate them illegally. There is, therefore, hope for ensuring that the identification process is completed by verifying the actual status of operating and abandoned sites. Local authorities are best placed to undertake this operation.

(2) Monitoring and Enforcement of Standards for Operating Hazardous Waste Management Facilities

There appears to be widespread agreement among industry, environmentalists, and federal and state authorities, in the light of the recently promulgated "Interim Final Rules for Hazardous Waste Management Systems" by EPA, that RCRA will minimize the risks to ground water from new hazardous waste management facilities. Opinions diverge, however, when addressing the regulations' effectiveness in dealing with existing on-site facilities which have obtained interim status permits. The table on page 4-11 shows that by far the larger number of operating facilities belongs to this group, hence risks for ground water pollution will exist as long as these facilities are allowed to operate in substandard conditions.

EPA acknowledges that: (a) it has legal authority under Subtitle C of RCRA to regulate any activity, emission, or release from a facility that is receiving hazardous waste and that there is no limitation in its authority over parts only of that facility which receive hazardous waste after a specific date; and (b) its authority to deny permission to conduct future waste management activity is one of the principal sanctions under the permit program. EPA has concluded that reasonable measures to address current ground water pollution attributable to waste placed before the date of permit issuance should be included among the responsibilities of the owner. A reason leading to that conclusion is that the nature of any corrective action would not be substantially altered by attempts to distinguish between wastes placed in the same unit at different times (Federal Register 1982a).

EPA, however, does not consider a permit under Subtitle C to be the appropriate mechanism for requiring clean-up of contamination from all previous waste management activity at a facility. In accordance with RCRA, regulations under Subtitle C are to become effective six months after they are promulgated. Thus, operators have the options either to close down a facility completely or to adopt proper design and operating measures to reduce the potential for ground water pollution.

EPA acknowledges that it will take several years to complete the process of calling in all permit applications and taking final action for all existing land disposal units. But it considers that by indicating to all hazardous waste management facilities receiving waste after the effective date of the Interim-Final Regulations that they will ultimately be subject to the monitoring and response program. This may provide a basis for substantial incentives for owners and operators to take reasonable steps to reduce the probability of facing long term responsibility for corrective action. However, the statement that "several years" will be needed to call in all permit applications introduces uncertainty in implementing the legislation.

In light of the above, the following observations may be made:

(1) Hazardous waste management facilities which will be closed down by their owners/operators before the date the EPA regulations become effective may pose risks for ground water contamination. No authority, other than CERCLA "Superfund" exists for cleanup operations, but they will be subject to the interium status post closure monitoring requirements. These requirements provide for the mechanism of the contaminant plume but do not provide assurance for corrective action.

(2) Hazardous waste management facilities which exist and continue to operate will do so under severe obligations by the law that they adopt proper design and operating measures to reduce the potential for ground water contamination. The fact that such contamination may have occurred prior to the date the regulations become effective is not considered a justification for avoiding the adoption of such measures. However, the new regulations do not require

cleaning contamination of the ground that occurred before the date of effectiveness of the regulations. It is therefore possible that some ground water pollution will occur from such facilities;

(3) Ground water pollution from currently operating on--site facilities may continue to occur until the facility with interim status obtains--or fails to obtain--their final permit. For this reason, EPA may consider defining more precisely the date, or year, by which all applications will have to be called in; and

(4) New hazardous waste management facilities have to abide by the new regulations which reduce to a mimimum the probability of ground water contamination.

(3) Cleanup

The cleanup of old hazardous waste dumping sites for which no responsible party can be identified is dealt with by CERCLA (Superfund). The implementation of CERCLA legislation has drawn considerable criticism so far. There is evidence that, apart from very acute cases of ground water contamination, "Superfund" support for cleaning up old dumping sites was very slow to come. This delay prompted the Environmental Defense Fund and the State of New Jersey, on the one hand, to file suits in federal court to require EPA to promulgate the plan by February 7, 1982. On the other hand, Exxon Corporation sued the State of New Jersey to return the funds paid into the state fund for the enactment of "Superfund" legislation (Deland 1981).

State authorities in the Southeast gave a mixed reaction when asked about the "Superfund" enforcement in their state. Some were very positive and some very negative. In most cases, their judgement derived from their success or failure to secure funds for cleanup. A pervasive criticism was that sites usually are chosen for cleanup because of the extensive press attention they have attracted. Another criticism dealt with the extent of the cleanup. There were cases where state authorities asked for more extensive operations than those EPA offered to cover by federal funds. They argued that the cleanup should remove not only the visual aspects of pollution, but the danger of ground water pollution as well.

Lastly, most state authorities were in agreement that ground water pollution will result from old operating or abandoned hazardous waste land disposal sites and that they are unable, in most cases, to finance the necessary cleanup operations.

The main drawbacks of existing legislation and its enforcement are the following:

- There is a very large number of old hazardous waste land disposal sites, hence it is not possible that they are cleaned during the five years that CERCLA will be enforced. The cleanup process will last for a much longer period of time if severe ground water pollution is to be avoided; and
- If CERCLA is to be extended for a longer period of time, or if new legislation is passed to deal with the problem (e.g., some new federal/state programs) it will be necessary that criteria for evaluating the extent and severity of potential hazards that may result from each site are established. Ground water pollution, its potential extent and severity should be one of these criteria. On the basis of these criteria, old sites have to be classified, and cleanup operations should begin for those posing the most acute hazards.

D. Small Generators of Hazardous Waste

The manifest system of RCRA does not apply to generators of less than 1000 kg/month of hazardous waste. In developing RCRA regulations, this limit was thought necessary given the very large number of such generators and the necessity that RCRA's enforcement be manageable. This exclusion may, however, represent a real threat for ground water pollution, because small generators could possibly dispose of their hazardous waste in the least costly way, irrespective of whether it is environmentally safe or not. Use of municipal landfills and sewers and illegal disposal along roadsides have been mentioned by state authorities. They also mentioned that small generators do not have the public relations problems that a large company has if it does not dispose of its hazardous waste in the proper way. Lastly, they indicated that the cost of disposal according to RCRA standards may be economically prohibitive for a small company.

Hazardous waste management company officers have also acknowledged the problems posed by small hazardous waste generators. They argue, however, that costs are not prohibitive because the maximum of 1000 kg/month is only about seven drums of waste. They have indicated that they have had a substantial increase of this type of customer. They agree that problems of transport exist, both economic and practical. One hazardous waste management company is using smaller trucks for the collection of hazardous waste from small generators. Some small hazardous waste generators make use of the services offered by hazardous waste brokers, who collect and store this waste before it is taken by the hazardous waste industry for treatment and disposal.

The regulation of small hazardous waste generators is a matter which may be dealt with by local and/or state authorities. For example, an extension of the manifest system to cover small generators will provide better knowledge of the quality and quantity of wastes, which will be useful in designing cost effective measures for the disposal of these wastes.

4.2.4 Conclusion

The next ten years or so will be the period of time when hazardous waste management needs to become an accepted service industry. RCRA and TSCA provide a regulatory framework which should help to ensure that this new industry operates with minimal adverse environmental impacts, particularly with respect to ground water contamination. Siting hazardous waste management facilities will remain a controversial activity and the main hurdle for the above developments. Experiences of states and local areas should be studied for their success or failure both in terms of providing the necessary hazardous waste management capacity and for protecting the environment.

4.3 NONPOINT SOURCE POLLUTION AND LAND USE PRACTICES

Summary: Nonpoint sources of pollution, which are closely related to land use practices, are important concerns for ground water quality protection. These include septic tank systems, intensive agriculture, urban development, energy and mineral extraction, dredge and filling operations, land application of wastewaters, construction, spills from transport, and other industrial activities. In several instances, improvements in technologies or in operating practices could reduce the threats to both surface and ground waters from these sources. However, in most cases the only way to effectively limit the threats to ground water is to regulate such activities in critical ground water recharge areas. At the present time, only in a few instances do federal, state, and local laws utilize land-use controls for the purpose of protecting ground water resources.

4.3.1 Nonpoint Sources

Nonpoint sources of pollution are important in the Southeast in terms of their effects on both surface and ground waters. Table 4-4 lists pollutants of concern for seven categories of nonpoint pollution. Chapter 2 included a review of the current extent and future trends in nonpoint sources of pollution, with a primary focus on surface water effects. Two nonpoint categories especially important for surface waters--urban runoff and agricultural runoff

TABLE 4-4: NONPOINT SOURCES OF GROUND WATER CONTAMINATION

Category	Pollutants of Concern
Leaks and spills	Hazardous chemicals Petroleum products Sewage
Septic tanks	Nitrates Organic chemicals Microorganisms Chlorides
Agriculture	Nitrates Pesticides Herbicides Microorganisms (feedlots)
Urban runoff	Heavy metals Microorganisms Organics
Mining	Acid mine drainage Various mine tailings
Petroleum development	Brine Toxic constituents of drilling muds Petroleum
Land disposal of waste waters	Heavy metals Microorganisms Organics Nitrates Other salts

--were addressed in more detail in that chapter. The purpose of this section is to describe problems and issues associated with protecting ground water from nonpoint source activities. Since nonpoint sources are intimately related to land use practices, an overriding issue is the need to incorporate ground water criteria into land use planning--especially in aquifer recharge areas. Following a summary discussion of the effects of various nonpoint sources on ground water, this section will discuss two categories in more detail--septic tanks and energy and mineral extraction.

The final part of this section will review more broadly the need for land use planning to protect ground water from nonpoint pollution sources.

A. Leaks and Spills

Based on a sampling of water well drillers in seven southeastern states, leaks and spills ranked as the most common contamination source requiring well replacement, with the most frequent pollutants being hydrocarbon products (Miller, Hackenberry, and DeLuca 1977).[1] Contamination can occur from leaky and ruptured petroleum product pipelines, petroleum product storage tanks, and sewer lines. The most frequently reported contaminants in the study region are from sewage and petroleum products. Leaks and spills can also occur from transportation and material handling accidents resulting in the release of pollutants to the environment.

Illustrative of these problems is the case of Dade County, Florida, where since 1972 over 50 cases of storage tank leaks have been reported (Dade County, Dept. of Environmental Resources Management 1980). In 1971, 1.5 million gallons of solvents were estimated to have been released to the ground water under Miami International Airport, less than one mile south of the Hialeah-Miami Springs well field. Numerous incidents of well contamination due to leaks and spills of petroleum products, usually gasoline, have been documented in Georgia. Other leaks and spills which have affected ground water supplies, including private drinking water wells are radioactive wastes in Florida, chromium in Alabama, and an increase in chlorides in wells in parts of Mississippi and Alabama (Miller, Hackenberry, and DeLuca 1977).

Because of the shallow water table in areas of North Carolina and Florida, underground storage tanks receive ground water and are corroded by it. Thus, they present a real threat to ground water quality. To a lesser extent, this is also true for pipelines. Along the southern coast of North Carolina, leaking storage tanks have contaminated several drinking water wells (North Carolina Dept. of Natural Resources and Community Development 1982).

The major cause of these accidental leaks and spills is attributed to "poor housekeeping" practices by business and industry, airports, service stations, and farms. Most spills or leaks are discovered after they have already polluted water supplies; usually residents complain that their drinking water has an objectionable taste and odor. Leakage from sanitary and storm sewers will likely continue due to the difficulty in replacing entire sewer systems.

---

[1] States included were Virginia plus our study area excluding Tennessee and Kentucky.

Many of these systems are old and in need of repair. Better environmental regulations, improved technology, and better training for hazardous material handlers and transporters can reduce the incidence of leaks and spills from pipelines, buried storage tanks, and transportation accidents.

B. Agriculture

Agricultural activities were discussed generally as a nonpoint source of water pollution in Chapter 2. In terms of ground water, a sampling of water well drillers in the Southeast indicated that contamination of wells by feedlots, pesticides, and fertilizers accounted for 10 percent of the cases of ground water contamination requiring well replacement (Miller, Hackenberry, and DeLuca 1977, 141). Pollutants of concern for ground water from these sources are nutrients (nitrogen and phosphorus), microorganisms, and pesticides (U.S. EPA, Office of Air and Water Programs 1973). Fertilizers (nutrients) and pesticides can pollute ground waters either by inflow from surface waters or by leaching through underlying soils directly into the saturated zone; organic residues and derivatives of many pesticides are extremely toxic and very stable. Thus, the intensity and frequency of applications of fertilizers, pesticides, and herbicides is an important issue in ground water quality protection.

Other sources of ground water quality degradation associated with agriculture include: (a) overpumping of ground water for irrigation, which can lead to depletion of the aquifer and a reduction of overall water quality (e.g., due to salt water intrusion); and (b) the heavy use of fertilizers and pesticides by home owners and pest control companies in urbanized areas.

In 1977 the Department of Environment Resources Management in Dade County, Florida, investigated high nitrate levels found in south Dade County wells, both public and private. It was found that much of the nitrate was entering the ground water system through leaching of agricultural fertilizer. The highest levels were noted in planting and harvesting seasons when no cover crops exist. Nitrate does not react with the limestone aquifer, but rather flows freely within the aquifer due to its solubility (Dade County 1980). Nitrate levels have recently been found to exceed both state and local drinking water standards in some South Dade canal waters and in certain domestic wells. Although the high nitrate levels are very localized, several residential wells and two public well fields draw their water supplies from this area.

C. Urban Runoff

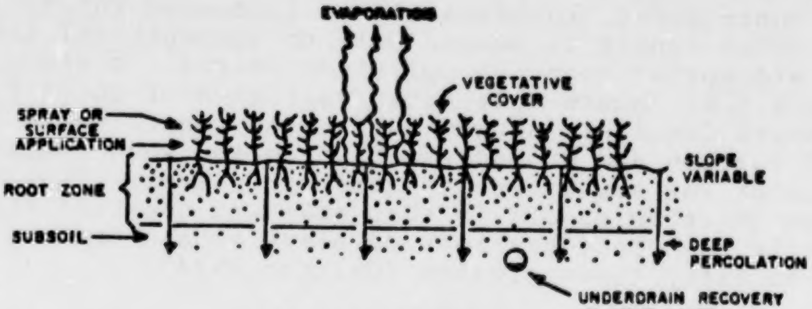
Urban runoff, discussed previously in Chapter 2, has become a serious concern in parts of the Southeast. Urban land use practices have resulted in an altered rate of storm water runoff and have contributed significantly to increased runoff in some cities. Urban runoff is second only to agricultural activities as the most widespread nonpoint pollution source. A study of urban runoff in a 1.67 square-mile urban watershed of Third Fork Creek in Durham, North Carolina, showed that urban runoff was a significant source of surface and ground water pollution when compared with the generation of raw sewage in the same study area. The organic concentration in urban runoff in that area was one-half that for raw waste, while the concentrations of heavy metals and solids ranged from two to fifty times greater (Colston 1974).

The Southeast region is projected to have the greatest population increases from 1980 to 2010, as compared to other federal regions (Science and Public Policy 1983), thus, increases in urban pollutant discharges are also expected to be greatest here. At present, the Southeast is estimated to contribute 16 percent of the U.S. total of water pollutant discharges in urban runoff (U.S. EPA, Office of Research and Development 1980). Almost all types of pollutants--suspended solids, toxic substances (including heavy metals), microorganisms, oxygen-demanding materials, nutrients, and oil and grease--are contained in urban runoff. Sources range from litter and animal wastes to landscape maintenance chemicals and surface-settling air pollutants.

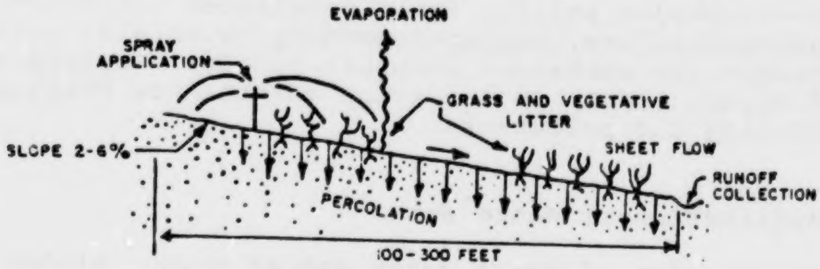
D. Land Application of Waste Water

Land application of waste water and/or sewage sludge has been encouraged for the following reasons (Weimar 1980): (a) recovery of nutrients for agricultural use; (b) reduction in the volume of waste to be processed at wastewater treatment plants; and (3) recharge of diminishing ground water supplies.

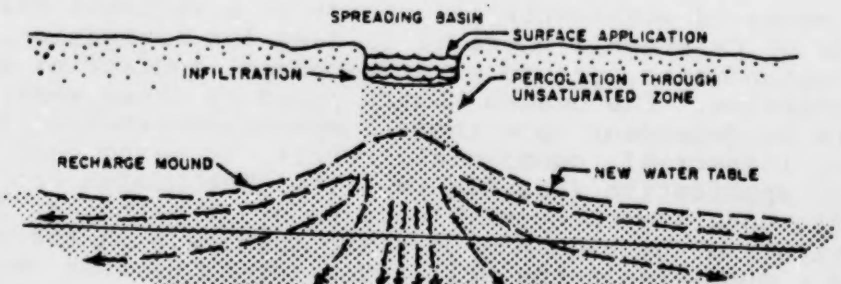
The reuse of wastewater is considered a valuable resource in the State of California where it is used for irrigation, recreational impoundments, ground water recharge, industrial uses, and fire protection. The health hazard posed by these wastewater effluents is dependent upon their composition--whether they are domestic, industrial, commercial, runoff, or mixed--and on the method of application (see Figure 4-1). The health concerns with these effluents are the possible transfer of pathogens from spray application and the presence of toxic chemicals in the wastewaters that can accumulate in the soil and reenter the food chain or migrate to ground water aquifers (Schaub and Sorber 1977; Burge and Marsh 1978; Straub 1973) (see Table 4-5). The most serious of these health concerns is believed to be long-term human exposure to trace concentrations of toxic chemicals (e.g., cadmium) which have been disposed of on land (Lazar, Testani, and Giles 1976; Larsen 1980).



SPRAY IRRIGATION



OVERLAND FLOW



RAPID INFILTRATION

Figure 4-1: Methods of land disposal of waste water.

Source: Miller, Hackenberry, and DeLuca 1977.

TABLE 4-5: SUMMARY OF CONTAMINATION LIKELY FROM LAND DISPOSAL OF DOMESTIC WASTE WATER

Parameter	Spray Irrigation	Rapid Infiltration
Nitrogen	Nutrients that are not used by plants or fixed in the soil can leach to ground water.	Significant quantities passed to ground water at most sites.
Phosphorus	Leaching of excess phosphorus is rare occurrence. Organic and clay soils mineralize the phosphorus.	Removal may be limited.
Organics	Some are broken down by microorganisms and used by plants. Can appear in ground water when application rate is highest or when in open soil, such as sand or gravel, with a high percolation rate.	Evidence is that little organic matter reaches ground water.
Trace Elements	Toxic compounds can be changed by the chemical reaction of cation exchange and can be rendered nontoxic by bacteria. Chemical precipitates formed can be leached out, however.	Retention may be limited.
Total Disslolved Solids	Leaching can occur and build-up is possible.	Build-up is possible.
Enteric Organisms	Usually are removed or die out and do not reach ground water especially if water table is kept low.	Spread of bacteria and viruses by insects or percolating water is of concern but unlikely under proper soil conditions.

Source: Miller, Hackenberry, and DeLuca 1977.

Burge and Marsh (1978) concluded that there was still a lack of evidence of just how hazardous the landspreading of sewage wastes is to humans. Evidence suggests that most bacteria and viruses are removed when wastewater is applied at a moderate rate to medium-to-fine texture soils, and that runoff is the greatest threat for movement of pathogens.

Gerba (1981) noted the growing number of studies associated with viral contamination of ground water as a result of land application of wastewater. He concluded that factors affecting virus survival in ground water are not well understood.

Drewry and Elizassen (1968) noted that most cases of viral contamination of ground water seemed to be a function of the virus migrating through fissured or channeled substrata rather than seepage through the soil itself. A number of studies have shown that viruses can move great distances in ground water but the factors affecting movement have not been studied directly (Wellings et al. 1975; Noonan and McNabb 1979).

Florida has over 2,500 permitted sites for land disposal of domestic wastewater with the majority (over 1,700) in central and southern Florida. An estimated 150 mgd are applied but little is known about the impact on ground water quality. Only a few of these sites, like that in St. Petersburg, are monitored on a regular basis (Franks 1981).

4.3.2 On-Site Sewage Disposal

A. Impacts

On-site disposal systems include septic tanks, cesspools, and privies. This section will focus primarily on septic tanks and cesspools; privies are not a major source of concern in the study area due to their local nature. A major concern in many locations is that the density of the septic tanks is greater than the natural ability of the subsurface environment to receive and purify effluents prior to their movement into ground water. In addition, the design life of many septic tank systems is on the order of 10-15 years. Due to the rapid rate of placement of septic tank systems in the 1960's and the fact that the usable life of many of the systems is being exceeded, more severe ground water contamination is beginning to occur (Canter, Knox, and Kamat 1982).

Septic tanks and cesspools discharge more wastewater directly into the ground water than any other source, and nationally they are the most frequently reported sources of bacterial and viral contamination (U.S., Council on Environmental Quality [CEQ] 1981). Approximately 17 million housing units in the U.S., or one-third of all housing units, dispose of domestic wastewater through the use of septic tank systems. About 25 percent of all new homes being

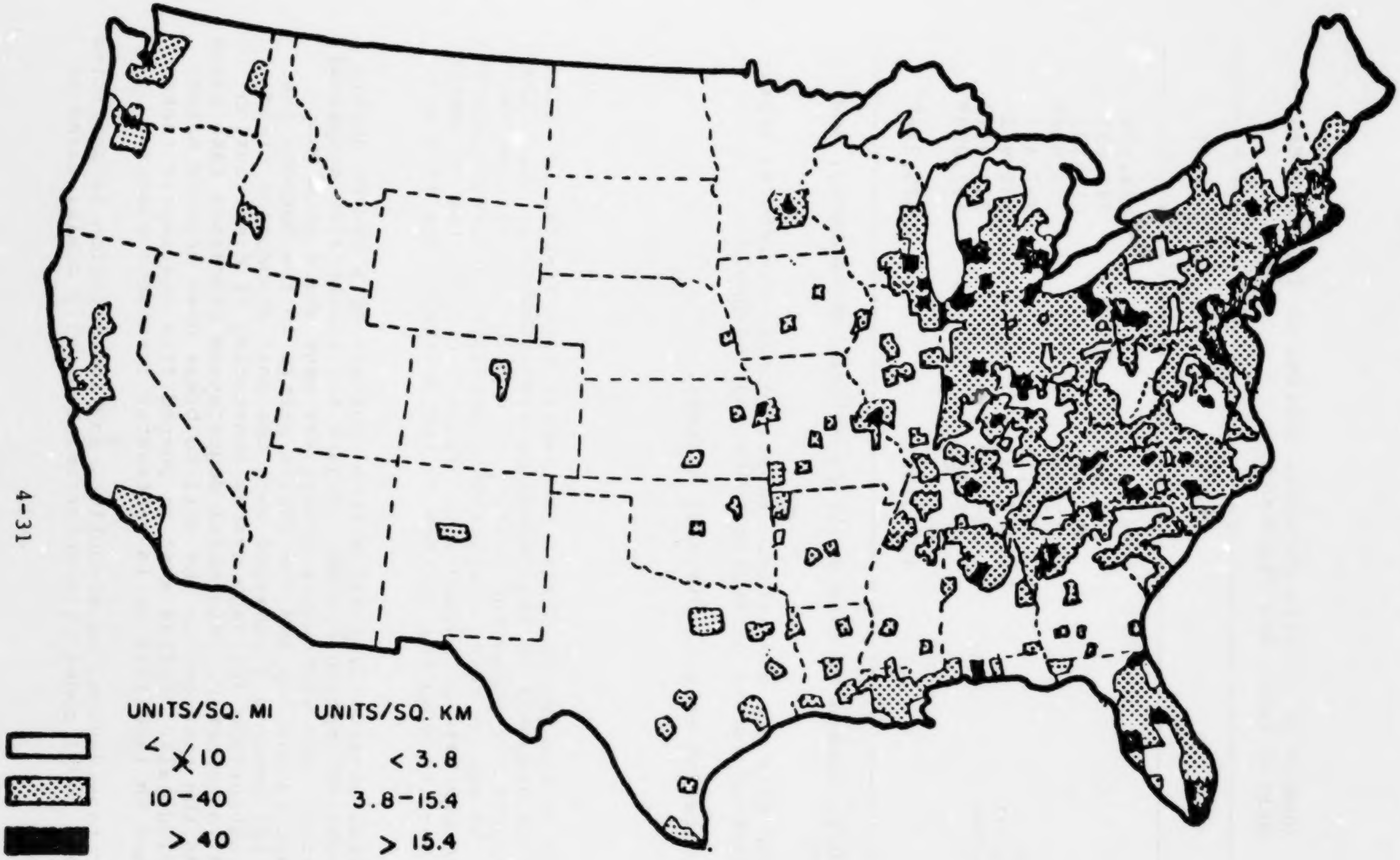


Figure 4-2: Density of housing units using on-site domestic waste disposal systems (by county).

Source: U.S. EPA 1977.

TABLE 4-6: NUMBER OF ON-SITE DISPOSAL SYSTEMS IN THE SOUTHEAST--SEPTIC TANKS AND CESSPOOLS

State	1970	1977
Alabama	385,345	584,524
Florida	938,352	981,097
Georgia	474,455	615,121
Kentucky	312,856	312,856[a]
Mississippi	209,115	357,497
North Carolina	687,572	882,932
South Carolina	334,210	334,211[a]
Tennessee	457,008	457,008[a]
Total	4,255,921	4,525,246[b]

Sources: U.S. Bureau of Census, 1970; Miller, Hackenberry, and DeLuca 1977.

[a] More recent data not available. These figures, therefore, represent the minimum number of septic tanks and cesspools.

[b] Minimum number of on-site disposal systems.

constructed in the United States use septic tank systems for treatment prior to disposal of the home-generated wastewater (U.S. EPA 1980a). Figure 4-2 shows the density of septic tank systems nationwide. As can be seen, the greatest densities of usage generally occur in the East and Southeast. Table 4-6 lists the estimated number of on-site disposal systems in the Southeast for 1970 and 1977.

A typical on-site disposal system consists of a buried septic tank and soil absorption system. Figure 4-3 illustrates a typical septic system. Raw wastewater enters the tank where scum and grease float to the top and the solids settle to the bottom; the clarified effluent is discharged into the soil absorption field through a subsurface drainage system consisting of distribution pipes laid in trenches. Microbial degradation processes take place both inside the tank and in the soil to break down organic materials. Periodically, solids must be pumped from the septic tanks and disposed in landfills or in wastewater treatment plants.

Septic tank design, construction, and installation is specified by state and local codes with enforcement usually administered at

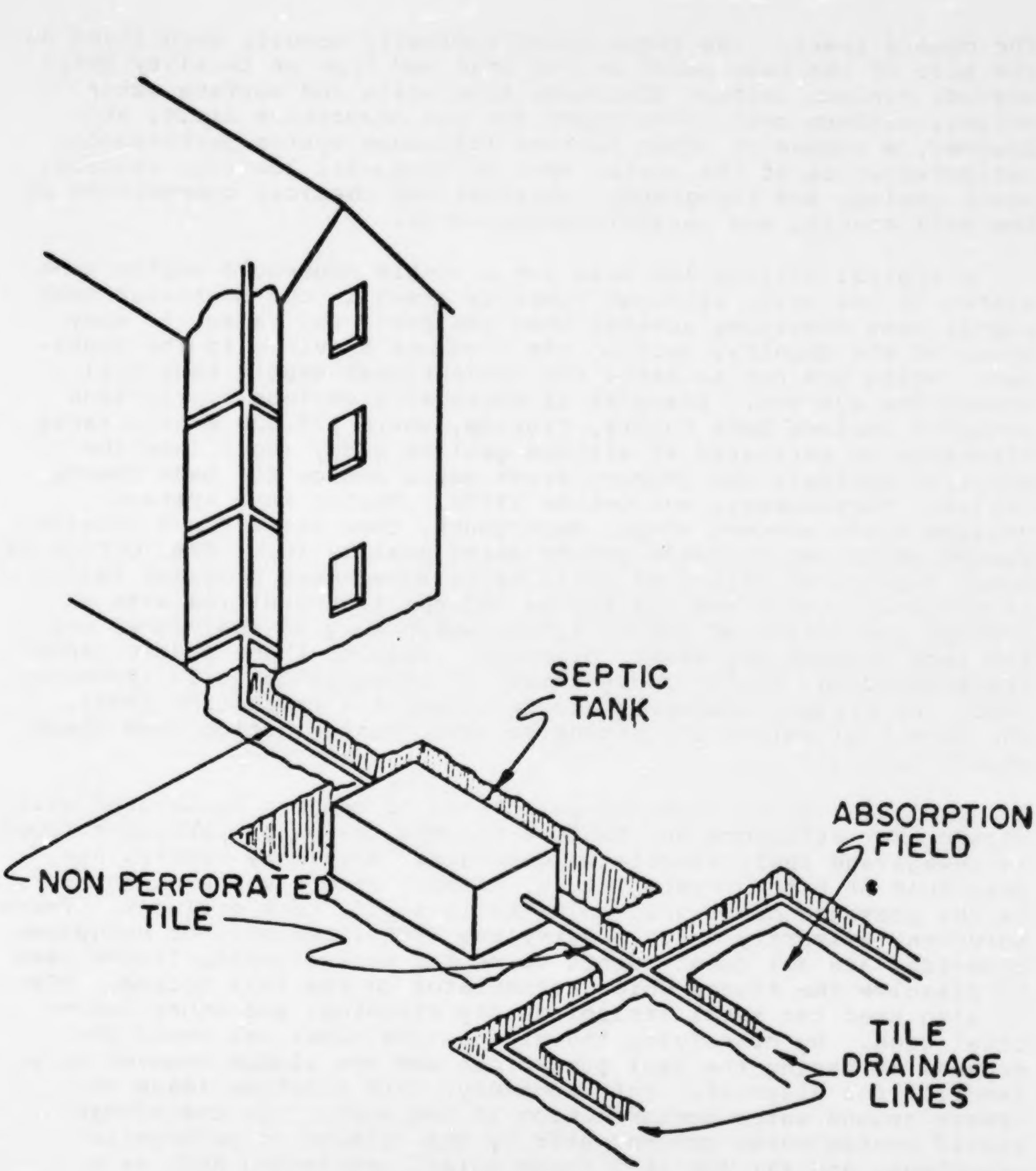


Figure 4-3: Typical on-site system.

Source: Scalf, Dunlap, and Kreissl 1977.

the county level. The regulations typically specify such items as the size of the tank based on the size and type of facility being served, minimum setback distances from wells and surface water bodies, minimum soil cover depth for the absorption field, etc. However, a number of other factors influence system performance; characteristics of the waste, rate of hydraulic loading, climate, areal geology and topography, physical and chemical composition of the soil mantle, and periodic maintenance.

A typical minimum lot size for a single household septic tank system is one acre, although numerous areas in the Southeast have septic tank densities greater than one per acre. Also, in many areas of the country, such as the Piedmont Province in the Southeast, soils are not suitable for conventional septic tank soil absorption systems. Examples of areas with serious septic tank concerns include Dade County, Florida, where 175,000 septic tanks discharge an estimated 40 million gallons a day (mgd) into the Biscayne Aquifer, the primary fresh water source for Dade County (Miller, Hackenberry, and DeLuca 1977). Septic tank systems release human wastes, soaps, detergents, food wastes, and chemical wastes which can threaten ground water quality (U.S. EPA, Office of Water Supply and Office of Solid Waste Management Programs 1977). In Kentucky, there are 114 cities and small communities with an average population of 100 to 3,500, which rely on individual septic tank systems for sewage disposal. Many of these septic tanks are located in shallow, saturated, or impermeable soils (Kentucky, Dept. for Natural Resources and Environmental Protection 1980). The potential exists for extensive areal contamination from these septic tanks.

Table 4-7 lists chemical pollutants of concern associated with septic tank effluents and Table 4-8 lists the major pathogens found in sewage and their associated diseases. A primary concern has been that of high nitrate levels. A more recent concern, however, is the presence of organic solvents in septic tank effluent. These solvents, primarily trichloroethylene (TCE), benzene, or methylene chloride, are all constituents of septic tank cleaning fluids used to dissolve the sludge which accumulates on the tank bottom. TCE is also used for metal stripping, dry cleaning, and other industrial uses. By dissolving the sludge, the owner can avoid the expense of having the tank pumped out and the sludge removed to a landfill for disposal. Unfortunately, this practice leads to severe ground water contamination in two ways: (1) the sludge itself contaminates ground water by the release of pathogenic organisms, and (2) TCE is a known animal carcinogen and, as a chlorinated organic, spreads with the ground water. TCE contamination has resulted in the closure of many public and private drinking water wells throughout the country most notably in California and Long Island, New York. The contamination is widespread, affecting both rural and urban areas, industrial and nonindustrial states (Council on Environmental Quality 1981). However, there are many potential sources of TCE as it is a widely used chemical, and

TABLE 4-7: CHEMICAL POLLUTANTS OF CONCERN FROM ON-SITE DISPOSAL SYSTEMS

Chemical Pollutants	Health Effects
Nitrates	Physiological distress Methemoglobinemia (>45 ppm NO_3)
Metals and heavy metals (Pb, Tn, Fe, Cu, Zn, Mg)	Toxic to humans in excessive concentrations
Chlorides, sulfates, potassium calcium, magnesium	Cardiovascular or renal disease
Toxic organic compounds (solvents and cleaners)	Possibly carcinogenic

Source: U.S. EPA. Office of Water Supply and Office of Solid Waste Management Programs 1977.

the relative contributions of septic tanks to pollution incidents is unknown.

Health effects from ground water contamination by septic tanks are a potential problem in the Southeast because of the sheer volume of on-site disposal systems in the area. Microbial contamination is not considered too great a threat unless the septic fluids are recycled so quickly through the aquifer that pathogenic organisms which are normally attenuated by the soil would be able to survive. Microbial contamination most frequently occurs on a local attributed to the septic tank and drinking water well being located too close to each other, or the well being placed downslope from the septic tank. Craun (1979) reported that from 1946 to 1977 there were 264 outbreaks of water-borne illness relative to contaminated ground water in the United States and that overflow from septic tanks and cesspools was responsible for 42 percent of those outbreaks.

B. Trends and Issues

Ground water contamination from septic tank systems may be individual, local, or regional in nature. While geology, soil, climate, humidity, and depth to the water table are all major factors in proper siting and installation of on-site disposal systems, density is becoming a source of concern with the growing development of housing in rural and suburban areas which do not have acess to

TABLE 4-8: MAJOR PATHOGENS FOUND IN SEWAGE AND DISEASES ASSOCIATED WITH THESE PATHOGENS

Organisms	Disease
Bacteria	
Salmonella spp.	Salmonellosis
Shigella spp.	Shigellosis
Mycobacterium tuberculosis	Pulmonary tuberculosis
Protozoa	
Entamoeba histolytica	Amoebic dysentery
Helminthic parasites (Intestinal worms)	
Ascaris lumbricoides	Ascariasis
Ancylostoma duodenale	Hookworm infection
Necator americanus	Hookworm infection
Taenia saginata (Beef tapeworm)	Taeniasis
Trichuris trichiura (Whipworm)	Trichuriasis
Viruses	
Poliovirus	Poliomyelitis
Coxsackievirus	Aseptic meningitis, gastroenteritis[a]
Echovirus	Aseptic meningitis[b]
Reovirus	Mild respiratory infection, gasteroenteritis
Adenovirus	Acute respiratory infection[c]
Hepatitis virus	Infectious hepatitis

Source: Burge and Marsh 1978.

[a] Two of the diseases caused by several serotypes of this virus. Diseases caused range from trivial to lethal.

[b] Diseases caused also include gasteroenteritis - see footnote "a" above.

[c] Other diseases include pharyngitis and infant pneumonia.

central sewer systems. Scalf, Dunlap, and Kreissl (1977) rank density of septic tank systems as the most important factor influencing regional ground water contamination. Much of this growth is in traditionally rural areas or small communities with inadequate waste disposal systems, thereby increasing the pressure for installing more on-site disposal systems. The use of septic tanks for domestic on-site dispoal will continue in spite of the many incidences of drinking water well contamination linked to septic tank discharges. There are alternatives for minimizing the extent of septic tank pollution, but they are often difficult to implement for the following reasons (Miller, Hackenberry, and DeLuca 1977; Moore, Gardner, & Associates 1979):

(1) Often acceptable alternatives for domestic waste disposal are not available in unsewered areas;

(2) Budgetary limitations at the local, state, and federal level make it increasingly difficult to expand public sewer systems to rapidly growing suburban and nonurban areas;

(3) Expansion of existing sewage treatment plants has been slowed as those plants upgrade their facilities to meet new treatment standards;

(4) Local residents may be unwilling to pay the cost of developing a central sewer system even when ground water contamination from septic tanks has already occurred in their area; and

(5) The length of time required for a public sewer system to become fully operational can be several years.

In addition to these concerns related to overall sewage treatment planning, two key issues to be dealt with in nonpoint contamination by septic tanks are the adequacy of existing regulations and the use of organic solvents and degreasers for cleaning the tanks.

(1) Septic tank regulation

A major issue in minimizing the potential for septic contamination of ground water supplies is the adequacy of existing laws and regulations governing septic tank design, siting, installation, and maintenance. Areas of concern include the movement of pollutants from the absorption field as determined by setback distances and minimum percolation restrictions; the flow pattern below absorption trenches which is determined by spacing between trenches of various widths; and environmental factors such as aeration, freezing, and evapotranspiration which is affected by the minimum cover specifications. Existing codes with regard to distance requirements and percolation tests for soil permeability--are not based on sound, scientific knowledge about what actually happens in the subsurface environment. The percolation test, for example, was developed over

50 years ago to test the absorptive capacity (permeability) of soil. However, highly permeable soils can be overloaded. This can allow both organic and inorganic chemicals and microorganisms to move rapidly through the soil to the ground water (Scalf, Dunlap, and Kreissl 1977; Hagedorn, McCoy, and Rahe 1981).

North Carolina has revised its method of determining site suitability from the percolation test to include on-site inspections which are conducted for topography, soil characteristics, depth to ground water, and depth to underlying bedrock. The Wilmington-New Hanover area uses a system of soil classification to determine the suitability of an area for septic tank systems (Wilmington-New Hanover Planning Dept. 1980). South Carolina is adopting this procedure.

(2) Use of solvents and degreasers

As discussed previously, ground water contamination by TCE an ingredient of septic tank solvents and degreasers, has recently been found in numerous drinking water supply wells. The result of three EPA surveys which measured selected volatile organic contaminants in drinking water supplies in 39 cities indicate frequent occurrences of TCE in both raw and treated ground water supplies. TCE is a known animal carcinogen and a suspected human carcinogen (Council on Environmental Quality 1981). Septic tanks are one of many likely sources of TCE. As indicated previously, the use of such solvents allows for pollution by releasing constituents normally retained in the solids at the bottom of the tank. A serious question exists as to the overall threat to ground water due to the use of these new chemical products and whether such products should be used.

4.3.3 Energy and Mineral Production

A. Impacts

The extraction and processing of energy and mineral resources can impact surface and ground water resources through several mechanisms.[1] Although the specific impacts vary from resource to resource and from site to site, basic causes of water quality and quantity changes are as follows:

- Any mining activity (including associated road construction) removes vegetation and disturbs the land surface, thereby increasing soil erosion and sediment loading to streams. This is primarily a problem for surface waters and is largely reversible with proper reclamation.

---

[1] For comprehensive analyses of ground water impacts and issues associated with mining see National Research Council 1979; 1981.

However, such changes can permanently alter aquifer recharge characteristics. In addition, mining of peat, phosphate, and other minerals in wetland areas can permanently alter the natural hydrology with potentially major ecosystem effects.

- Mining disturbs the subsurface environment with two effects: (1) an increase in the dissolved solids content of ground water; and (2) exposure of previously unexposed minerals to air and water with resulting changes in the natural geochemistry. Acid mine drainage, a major problem in coal mining areas of Kentucky, Tennessee, and Alabama, is the best known example of this second type of impact. Such impacts can be controlled to some extent but not entirely prevented, and the pollution threats can continue long after active mining operations cease.

- Mining and drilling operations can directly disrupt aquifer systems leading to changes both in quality and quantity of ground water. For example, mining can cause nearby wells to go dry and drilling can provide pathways between saline and fresh aquifers.

- All energy and mineral extraction and processing activities create some amount of waste requiring disposal. For example, coal mining wastes (gob) can be a major source of acid mine drainage. Phosphate ore processing requires disposal of large volumes of wastes containing radionuclides and other contaminants; this is a major source of pollution in Florida and an increasing problem in Tennessee and North Carolina. Devonian oil shale production in Kentucky, Tennessee, and Alabama would also require disposal of huge volumes of waste. Finally, oil production usually involves disposal of brine, either by reinjection or to surface holding ponds; this has been a significant source of ground and surface water pollution in the past, and currently is an important source of surface water pollution in parts of Kentucky.

There are numerous examples of such pollution problems in the southeastern states (see, for example, Miller, Hackenberry, and DeLuca 1977), but there have been no comprehensive studies or surveys to determine the overall extent of ground water degradation from mining and mineral processing activities. In a recent comprehensive study of the effects of coal mining on ground water by the National Research Council (1981, 2), it was concluded that:

> To date, the ground water effects and their attendant impacts--with the exception of acid mine drainage in the eastern United States--have been confined to relatively small areas. In future decades, increased levels of coal mining, together with greater reliance on ground water

resources for other purposes, are expected to increase the diversity and severity of the effects and impacts to levels of regional or national concern.

Table 4-9 shows the land areas that have been impacted by mining from 1930 through 1980 by state and commodity.[1] Kentucky had the largest land area affected (2.1 percent of its total land area), most of which was due to coal mining. Kentucky ranked second nationally (behind Pennsylvania) in the total land area impacted by mining. Florida ranks second in the study area (and sixth nationally) due to the large amount of phosphate mining. Eighty-two percent of the total land area affected nationally by phosphate mining occured in Florida. Alabama and Tennessee were also relatively large mining states (Alabama ranked ninth nationally), due mostly to coal mining in both states, iron ore production in Alabama--which has been discontinued since--and phosphate mining in Tennessee. The other four states were not major mining states, with mining having impacted less than 0.2 percent of the total land area in each state through 1980.

B. Future Trends

Table 4-10 presents one set of current and projected coal production levels for the Southeast (U.S. Congress, Office of Technology Assessment 1979; U.S. Dept. of Energy, Energy Information Administration 1981). Overall, the proportion of U.S. production from this region is projected to decline from 22 percent to 15 percent between 1980 and 2000, even though the absolute tonnage increased by 23 percent. Surface mining tonnage is projected to decline, while undergound mining is projected to experience a 59 percent growth. While such projections are reasonable estimates of possible future coal production in the study area, actual production levels will be determined by many factors such as total energy demand patterns, developments in the nuclear power industry, and environmental regulations, all of which are highly uncertain at the present time.

Table 4-11 shows current and projected earnings for nonfuel mining--both metal and non-metal--through the year 2010. Nonmetal mining is projected to roughly double over this thirty-year period. The largest absolute increases occur in Florida and Georgia. Overall in the region metal mining is much less important than nonmetal mining. Although the data is incomplete (due to data withheld to protect individual company confidentiality), for the states with complete data there is a 50 percent growth in metal mining earnings --almost all of which occurs in Tennessee.

---

[1] Note these figures exclude oil and gas production.

TABLE 4-9: LAND[a] UTILIZED BY THE MINING INDUSTRY[b] IN THE U.S. IN 1930-80, BY STATE AND SELECTED COMMODITY (thousands of acres)

State	Bituminous Coal	Iron Ore	Phosphate Rock	Sand and Gravel	Stone and Clay	All Other Commodities	Total[c]	% of Total Land Area Used For Mining
Alabama	105	7.5	0	9.3	23.6	0.5	146	0.39
Florida	0	0	222	9.7	34.8	31.2	298	0.86
Georgia	<1	0.4	0	4.8	46.2	3.0	55	0.15
Kentucky	503	0	0	6.8	24.0	0.1	533	2.09
Mississippi	0	0	0	10.5	6.2	0	17	0.06
North Carolina	0	<0.1	5	14.0	30.2	5.7	55	0.18
South Carolina	0	0	0	7.0	13.6	0.2	22	0.11
Tennessee	42	<0.1	22	9.9	31.2	1.7	106	0.40
Total for Southeastern States	649	7.9	249	72	209.8	42.4	1,232	0.52
U.S. Total[c]	2,700	121.0	270	960	982	450.0	5,700	0.25

Source: Johnson and Paone 1980.

[a] Includes area of surface mine excavation, area used for disposal of surface mine waste (includes coal, 1930-71 only), surface area subsided or disturbed as a result of underground waste, and surface area used for disposal of mill or processing waste. Excludes areas used for haulroads, fresh water reservoirs, railroads and public highways to edge of mining properties, and streams affected by acid drainage and sedimentation.

[b] Excludes oil and gas operations.

[c] Data may not add to totals shown because of independent rounding.

TABLE 4-10: COAL PRODUCTION PROJECTIONS[a]
(millions of tons per year)

Type	Eastern Kentucky	Western Kentucky	Alabama	Total Southeast	Total U.S.
Surface					
1980	49.6	21.4	16.9	87.9	492.2
1985	36	21	12	69	260
2000	40	28	10	78	925
Underground					
1980	59.6	19.6	9.5	88.1	337.5
1985	50	20	15	85	335
2000	85	33	27	145	580
Total					
1980	109.2	41.0	26.4	176.7	829.7
1985	86	41	27	154	955
2000	125	61	37	223	1,505

Source: Compiled from U.S. Congress, Office of Technology Assessment 1979, 48, and U.S. Dept. of Energy, Energy Information Agency 1981, 5.

[a]The projections assume a 100 Q energy demand by the year 2000.

Oil and gas production from the study area is small compared to the rest of the nation. In 1979 crude oil and natural gas production accounted for less than 4 percent and 2 percent respectively of the U.S. totals (Science and Public Policy 1983, 6-14). However, as is true throughout much of the U.S., the increase in oil and gas prices during the 1970's led to large increases in exploration and development activities in the Southeast (see Table 4-12). For example, the total wells drilled more than doubled between 1970 and 1981; most of this activity occurred in Kentucky and Mississippi. For example, Alabama has experienced an upsurge in oil and gas activities in recent years. State figures show that there were 23 producing oil and gas fields in Alabama in 1971; by the beginning of 1981, the number of fields had increased to 102 (McCaslin 1981). However, levels of oil and gas drilling activities over the long term are unknown. Oil and gas prices decreased in 1983 and drilling decreased in many parts of the South.

TABLE 4-11: MINING EARNINGS BY INDUSTRY BY STATE--1978-2010
(millions of 1972 dollars)

State	Metal Mining			Nonmetal Mining (excluding fuels)		
	1978	2010	% Increase	1978	2010	% Increase
Alabama	a	0.6	a	22	44	100
Florida	a	9	a	92	179	95
Georgia	0.5	0.7		73	151	106
Kentucky	0.1	0.2	200	27	61	126
Mississippi	0	0	0	11	29	103
North Carolina	0.05	0.2	100	46	86	87
South Carolina	0	0	0	16	38	138
Tennessee	16	24	50	33	64	94
Southeast	a	34.6	a	320	652	104

Source: Calculated from U.S. Dept. of Commerce, Bureau of Economic Analysis 1980.

[a]Data witheld to protect individual business confidentiality.

Other energy resources which could be potentially important in some areas of the Southeast in the future include oil shale and peat. For an overview discussion of these resources in the Sunbelt (see Science and Public Policy 1983, Ch. 6).

C. Issues

As energy and non-fuel mineral production activities grow, threats to surface and ground waters will also increase. Although some degree of water contamination and hydrologic modification will always occur, adverse impacts can be reduced through careful planning and operating practices. One overriding question is the degree to which impact mitigation practices are carried out by industry and by state and federal agencies. Another major

TABLE 4-12: TOTAL OIL AND GAS WELLS DRILLED[a]

State	1970	1975	1982
Alabama	45	110	214
Florida	25	46	30
Georgia	4	3	2
Kentucky	809	918	3,144
Mississippi	556	451	630
Tennessee	50	203	315
Total	1,489	1,728	400
			4,420
U.S. Total	28,120	37,235	86,290

Sources: American Petroleum Institute 1978 and updates; McCaslin 1983, 104.

[a] Total wells drilled includes both exploratory and development wells; excludes service wells; stratigraphic and core tests.

question will be whether such activities should be limited in some areas based on a need to protect critical ground water resources. More specifically, some of the key issues which need to be addressed are:

(1) Mine Planning and Impact Mitigation

The federal Surface Mine Control and Reclamation Act (SMCRA) has extensive regulations governing planning, operating practices, reclamation, and monitoring in order to mitigate ground and surface water impacts from coal mining; but, similar requirements do not exist for other types of mining. For example, Section 507 (b) (11) of SMCRA requires that before a permit can be issued for a new coal mine, a determination of the probable hydrological consequences be made. Section 508 (a) (13) requires a detailed description of the measures to be taken to assure the protection of surface and ground water quality, both on- and off-site and the right of present users to such water.[1] Section 515 specifies that measures be taken to prevent water from coming into contact with toxic materials and that acid and toxic water be treated before being released to waterways (Chisholm 1981, 139). Although such regulations are complex and controversial due to their economic effects, such requirements for all types of mining activities may be necessary to protect ground water resources.

---

[1] Although these regulations exist and considerable improvements have been made, this is not meant to suggest the problems have been solved. Many scientific/technical uncertainties exists as to the best means for protecting ground water (and in most cases nondegradation is impossible to achieve) (see National Academy of Sciences 1981) and due to federal budget cuts in these programs there is some question as to how vigorously the regulations will be enforced.

States generally rely on general water-pollution control statutes to protect water resources from noncoal mining activities. Although the regulations vary considerably from state to state, generally provisions are directed only at surface water quality. "Rarely is the ground water contamination potential of mining operations recognized" (U.S. EPA, Office of Water Supply 1977).

(2) Oil and Gas Drilling Regulation

Given continued production of brines from existing fields and the projected increases in oil and gas exploratory and development drilling, there will continue to be risks of ground water pollution. On the one hand, many of the practices which led to water pollution from oil and gas operations have been eliminated by state regulations and improved industry awareness and training. On the other hand, three types of regulatory problems exist which increase risks to ground water. First, the responsibility of enforcing drilling and brine disposal regulations usually lies with state oil and gas agencies which are primarily concerned with promoting efficient oil and gas development. This raises the issue as to whether environmental protection might be better served if enforcement were the responsibility of state environmental agencies (see, e.g., Miller, Hackenberry, and DeLuca 1977). Second, there have been concerns raised that regulations are not adequately enforced due to lack of trained personnel and inadequate funding (U.S. EPA, Office of Water Supply 1977, 319). Finally, there is often a lack of accessible data on boreholes drilled for both exploration and development purposes which is an important need when assessing and controlling potential ground water pollution (National Center for Ground Water Research 1980a).

(3) Plugging of Abandoned Wells

The leakage of contaminated or highly mineralized water through abandoned production wells and unplugged exploration holes has led to a number of ground water pollution problems (Table 4-13) (Fairchild, Canter 1982). Only recently has the potential magnitude of this problem been realized by the scientific community and regulatory agencies, and the full impact may not be recognized for years to come. In response to this problem, the National Water Well Association developed a set of recommendations in an effort to offer states a model for well abandonment legislation and regulation (Gass, Lehr, and Heiss 1977). An important need is state programs to deal with wells previously abandoned; without such retroactive recourse, vast numbers of wells would remain a threat.

TABLE 4-13: GROUND WATER POLLUTION CASES BY POLLUTANT SOURCE AND STATE

State	Drilling and Production	Pits	Abandoned Wells	Brine Disposal	Other	Total
Alabama		2			1	3
Arkansas		1		1		2
California		1		1		2
Colorado		1	1		large no.	2
Georgia			1			1
Illinois				1		1
Kansas		1		1		2
Kentucky	1		2	1		4
Louisiana	1	1				2
Maryland					1	1
Michigan			1			1
Mississippi		1				1
Montana		1				1
New Mexico		2				2
New York	1		2		1	4
Ohio		3	1			4
Oklahoma	7	7	11	1	1	27
Pennsylvania		1			30	31
Texas	13	3	30	20		66
West Virginia			2			2
Total	23	25	51	26	34	159

Source: Fairchild and Canter 1982.

(4) Research and Monitoring

Although there has been much research on the hydrologic effects of mining and well drilling, there remains a considerable amount of uncertainty as to the future impacts on ground and surface water that will result from energy and mineral development and the effectiveness of alternative mitigation measures. A variety of research and monitoring programs will be required if the threats to ground water are going to be better understood and controlled in the future (see, e.g., National Center for Ground Water Research 1980a and 1980b; Miller, Hackenberry, and DeLuca 1977). For example, the extent of ground water degradation from energy and mineral development is often unknown because there is little predevelopment monitoring to determine natural or baseline conditions prior to the commencement of mining, except in the case of coal mining as required under SMCRA. In order to better understand the impacts and the effectiveness of possible controls, baseline conditions need to be determined through predevelopment monitoring.

4.3.4 The Importance of Land Use Controls

This section has described several categories of nonpoint source pollution and their potential impacts on ground water quality. By definition, nonpoint sources are diffuse and are directly related to land use practices. Although certain technological and management controls can be used for each source to reduce threats to ground water (e.g., lining of landfills to eliminate leaching, street sweeping to reduce urban runoff pollution, or agricultural practices that reduce pesticide usage), in practice, the release of pollutants from such activities cannot be completely controlled. Thus, if ground water quality is to be better controlled, such activities would have to be restricted in critical aquifer recharge areas.

Several researchers have stressed the intimate connection between land use and ground water quality (e.g., see Tripp and Jaffe 1979). Ground water recharge areas are particularly susceptible to pollution and contamination due to the very characteristics that make them recharge areas; the loose-grained, unconsolidated deposits which provide for rapid infiltration and recharge to the aquifer also provide a pathway for pollutants to enter the aquifer. The federal government has seen the need to protect critical recharge zones of "sole-source aquifers" (Sec. 1424 [e] Safe Drinking Water Act 1974). However, the sole-source aquifer designation pertains only to projects involving federal funding and is the only federal provision utilizing recharge zone protection as a ground water management strategy. In only a few instances do local or state governments in the Southeast explicity use ground water protection criteria in formulating land use plans or controls.

4.4 GROUND WATER MONITORING

Summary: There are problems associated with ground water monitoring and data management in the Southeast due to complexities of ground water resources: they are widespread, their geohydrology is not always understood, and pollution sources are numerous. It is likely that managers will never have all the information they would desire for efficient management.

Problems originate from lack of coordination and information exchange among agencies involved, inadequate technical support for well networks and sampling, inconsistent or conflicting terminology associated with aquifer zones; and inadequate utilization of existing data bases.

4.4.1 Introduction

The lack of adequate information about ground water pollution is likely to be a continuing problem in the Southeast. In part this problem is characteristic of ground water resources: aquifer systems are typically large and complex; pollutants move slowly and often in narrow plumes; and toxic substances, which may originate from many surface and underground sources are typically in low concentration. Ground water monitoring problems also are related to technical difficulties of how monitoring is conducted, the cost of monitoring programs, how the information is made available and used, and the institutional arrangements for developing and using data.

The material in this section is drawn from existing reports as well as from a telephone survey which was made to provide more specific examples of ground water monitoring and data management problems in the Southeast. The survey was conducted during August and September 1982. Appendix B provides a summary of agencies contacted. This section describes existing programs and institutional arrangements for monitoring and then discusses examples of selected problems and issues.

As discussed in Chapter 2, the geohydrology of ground water resources in the Southeast is by no means homogeneous. Monitoring problems vary among and within the states, in part reflecting the nature of the resource, its level of use, and known or potential pollution problems. In the nonglaciated central region (i.e., primarily Kentucky) water movement in the consolidated formations is often quite slow, making early detection of pollution even more difficult. In the Piedmont and Blue Ridge region the fractured rocks and isolated nature of aquifers presents a major problem in developing any comprehensive monitoring plan. In the Coastal Plain the large aquifers, comprised of numerous strata, present monitoring difficulties due to the large scale of the ground water resources. Combined with the site-specific nature of pollution sources and land use patterns these characteristics tend to complicate any evaluation and comparison of state monitoring approaches.

The objectives of a ground water monitoring program generally are to collect, manage, and analyze data necessary for agencies to fulfill their statutory responsibilities (Hampton 1976). Data may be needed for a variety of purposes:

- Provide background information on quantity and quality;
- Detect quality trends;

- Identify and assess causes of pollution;
- Formulate and verify computerized aquifer models;
- Establish water quality standards and effluent limits;
- Formulate regulatory and management actions; and
- Provide data for compliance and enforcement.

A call for more and better ground water monitoring is frequently an automatic reaction to needs for policy formulation or for specific ground water problems. Although ground water monitoring data, suitably organized, is very important to policy formation, implementation, and enforcement, other types of information, such as land use data are also useful for effective management (see chapters 6 and 8). A range of approaches have been developed by government agencies in order to achieve these policy and problem solving objectives, as discussed below.

4.4.2 Existing Institutions

Ground water quality monitoring is conducted or sponsored by agencies at federal, state, and local levels. To a large extent both state and local monitoring activities are in response to federal programs, although a wide variation in implementation occurs among the states.

A. Federal Programs

Both EPA and the U.S. Geological Survey (USGS) have programs to monitor ground water. The USGS investigates the occurrence, quantity, quality, and movement of ground water and collects and disseminates much of the ground water data nationwide. The USGS maintains the major existing data and bibliographic files used by state governments and private industry (see Table 4-14). It conducts its field programs from one or more divisions in each of the eight southeastern states. These water resources divisions often provide technical expertise to state management agencies and conduct cooperative and cost sharing data development and monitoring activities (see Table 4-15).

The USGS Regional Aquifer System Analysis Program is a major USGS activity with the objective of providing a comprehensive understanding of the hydrogeology of the nation's major aquifers. There are three RASA studies currently underway in the southeastern states (Bennett 1979): (1) the Southeast Carbonate Aquifer Study that is assessing ground water quality in parts of Alabama, Florida, Georgia, and South Carolina was initiated in FY 1979; (2) the Southeast Coastal Plain Aquifer Study that is assessing

TABLE 4-14: USGS AND EPA DATA BASES

Common Acronym	Name	Content Summary	States Whose Agencies Commonly Use Data Base
USGS			
WATSTORE	Water Data Storage and Retrieval System	Major USGS data base that contains data on surface and ground water quality, availability, and use.	All states except Georgia, which uses only the GWSI subfile
GWSI	Ground Water Site Inventory	A subfile of WATSTORE that provides data on well location, logs, and construction features.	All states
NAWDEX	National Water Data Exchange	An indexing system to inform users of available hydrologic data (flows and quality).	All states
NWUDS	National Water Use Data System	States aquire data on water withdrawal and use. Storage and dissemination system maintained by USGS (a part of WATSTORE).	All states
EPA			
MSIS	Model State Information System	For reporting use of public water supplies. Contains some quality information.	Florida and Mississippi
STORET	Storage and Retrieval of Environmental Data	Water quality data for surface and ground water. State and local governments can store their data. Contains analytical software.	Alabama, Florida, and South Carolina

TABLE 4-15: GROUND WATER MONITORING AND DATA MANAGEMENT OF USGS[a]

State	No. of Water Level Wells Continuous	 Periodically	No. of Water Quality Wells	Selected Special Study Area
AL	32	240 semi-annually	100	--
FL	435	2,520 semi-annually	700[b]	5 studies--3 of these have some type of ground water monitoring
GA	200	96 annual plus 700 periodically	185 monthly, rest annually or every 5 years; on coast about 2,000 wells for salt water intrusion monitoring	Planning for increased use of ground water for irrigation
KY	75	175 annual	100	5 recent studies--one applied 4 ground water models in surface mined areas. Another examined water quality data
MS[c]	200	--	200 once every 5 years for salt water intrusion	Lee County--digital model on ground water resources; adequate water supply study in Adams City, Delta area
NC	53 (95% in coastal plain)		--	Aids in selection of wells for municipal supply (Mt. Piedmont). Ground water monitoring of hazardous waste site at Marine Base in Cherry Pt.
SC	15	45 semi-annually	5	Future monitoring radioactive waste site--Barnwell, SC (make nuclear bombs)
TN	24	12	--	Model of pollutant transport--Shelly County. Radioactive ground water monitoring--Oak Ridge

-- None or uncertain

[a] Based on a selected phone survey to USGS offices in each state (See Appendix B). Data should be interpreted with caution and are not based on USGS documents.

[b] USGS monitors within the 5 Florida Water Management Districts and these districts also do their own monitoring.

[c] Cooperates with Bureau of Land and Water Management, also has electric logs, water well drillers records since 1955--70,000 wells, computerized data for wells <50 gpm.

unconsolidated cretaceous aquifers was initiated in FY 1980; and (3) the Southeast Coastal Plain Sand Aquifer Study initiated in FY 1980 is making use of ground water models to evaluate the long-term effects of increased pumpage and deep waste injection wells. The studies are aimed at providing a technical understanding of aquifer characteristics, which should also provide information useful in managing ground water resources.

EPA activities in ground water monitoring include gathering data related to its broad environmental mission, as well as for the protection of drinking water supplies and protection from hazardous and toxic waste disposal. Specific monitoring studies are conducted by EPA's Laboratories. However, EPA's major activities have been in sponsoring state conducted studies, such as through the 208 Program of the Clean Water Act and the Safe Drinking Water Act reporting programs.

Quality assurance monitoring of potable water supplies required by EPA involves periodic sampling to determine whether drinking water standards are violated. Sampling and laboratory analysis are carried out by the water utility, but the state must create the program, compile the data base, determine when standards are violated, and initiate required action to protect public health.

The SDWA also required EPA to establish a program to prevent and control underground injection wells which might endanger drinking water sources. The EPA established minimal requirements for state Underground Injection Control (UIC) programs and the states could comply with federal regulations or develop their own UIC programs. Six of the eight southeastern states are developing their own programs to regulate deep well injection. In two states, Kentucky and Tennessee, EPA will regulate well injection and run the UIC Program (see Section 4.5.2). In the UIC programs, well operators are required to monitor the mechanical integrity of their wells. Operators of wells disposing of hazardous wastes into or above drinking water sources are required to perform weekly monitoring of the ground water. The operator sends these reports to the state agency while the states report the summarized information to EPA.

B. State Institutions

All of the southeastern states have two or more agencies with divided responsibilities for gathering data on ground water availability and use, and on ground water quality. Typically a geological survey, water resources council or department of natural resources has use and availability data, and a health department or environmental control agency has water quality responsibility. North Carolina is one exception, where the Department of Natural Resources and Community Development generally exercises both functions, although community water supplies are generally managed through the health agency, the Department of Human Resources.

States operate monitoring programs to assure drinking water quality and to protect water supplies from pollution sources. The number of public water supply systems in the eight states (community and noncommunity) ranges from 1,200 in Tennessee to 5,300 in Florida. Over 80 percent of these systems have less than 5 wells, although a few urban systems may have as many as 20 wells. Wells used for drinking water supplies must be monitored in accordance with the SDWA. Bacteriological determinations must be performed once a month and complete chemical analyses every three years. Radiological determinations are performed every eight to ten years. Personal communications with representatives of individual state agencies concerned with ground water indicated greater noncompliance in Florida and Mississippi. This does not necessarily mean that these states have more water quality problems; rather they may have better reporting and tracking of water quality problems. Most noncompliance was caused by bacterial contamination. The other main cause of noncompliance was radioactivity in Florida and South Carolina.

The states also perform monitoring tasks in response to complaints of water well contamination, although most of this is done by county health departments and is not coordinated by a state ground water agency. Complaints that lead to monitoring range from an average of 5 per month in Florida to 40 per month in North Carolina (North Carolina Dept. of Natural Resources and Community Development 1982; Florida Dept. of Environmental Regulations 1982).

State programs also exist for tracking ground water use. Ground water pumpage or use reports are required in all southeastern states except Alabama, Mississippi, and Tennessee. Florida uses its own computerized ground water tracking and reporting system in addition to federal systems. All states use the National Water Use Data System (see Table 4-14).

In South Carolina, passage of the Water Use Reporting and Coordination Act of 1982 was the beginning of an effort to develop a comprehensive data base on water resources to improve management options in times of emergency. Measurements for users of more than 100,000 gallons per day are estimated to include 95 percent of the water use by volume. The State Department of Health and Environmental Control has an extensive monitoring effort based in its district offices, and it is cooperating with the USGS in developing the WATSTORE data base. However, comprehensive analysis of pollutants is not routinely performed, and many individual drinking supplies are tested only upon the request of the owner.

The need for reliable and useful ground water information in Georgia was accentuated by the droughts that occurred in 1977 and 1978 and the rapid growth of irrigation systems. The Georgia Water

Use Data Project, a joint effort of the USGS and the Georgia Geologic Survey, was begun in response to the need for readily accessable site-specific water-use data. Information on municipal, industrial, irrigation, rural domestic, and power-generation water use is now entered in a systematic data base. Municipal and industrial water users are inventoried and records created for each point of withdrawal and discharge. Also, agricultural users withdrawing more than 100,000 gallons per day are required to provide information through the county agents to the state.

Data management studies are also conducted in the Southeast at the substate level. As an example of substate regional monitoring the South Florida Water Management District (one of five in the state) initiated a water quality network to monitor the changes that affect the ground and surface water interactions on a large scale district-wide basis. Land discharges to surface waters as well as canal percolation into aquifers are measured to better integrate water management (South Florida Water Management District 1980).

At the county level, for example, monitoring in Dade County, Florida, is being conducted to expand the ground water drinking water network into an areal quality network. This program was initiated in 1981 and integrates land use information with water quality information. Forty-five wells are monitored twice annually for pollution indicators such as bacteria and total dissolved solids while indicators such as trace metals, pesticides, herbicides, and volatile organics are monitored relative to land use or suspected pollution (Florida Dept. of Environmental Regulation 1982).

4.4.3 Problems and Issues

The following sections address the kinds of problems resulting from current institutional arrangements. These include technical problems such as dealing with how monitoring is conducted, economic problems and institutional problems such as deficiencies in data coordination.

A. Technical Limitations

Information on aquifer characteristics and use patterns is limited because of two types of technical problems: (1) limited data reconnaissance and reporting; and (2) limitations in data interpretation. Personal communication with staff of state ground water management agencies indicates that a lack of information on aquifer characteristics and use patterns generally exists, and that these limitations impede effective management.[1]

States also may have limited numbers of water level observation wells. Staff in agencies in Georgia, Kentucky, North Carolina, South Carolina, and Tennessee suggested that additional observation wells would improve their monitoring programs.

Lack of timely and reliable information on water use is a deficiency in effective ground water management in the Southeast. Based on the telephone survey with agencies from all the eight southeastern states (Appendix B), one problem is lack of information on current ground water uses, particularly in Georgia, North Carolina, and South Carolina. All the states indicated difficulty in obtaining data on intended uses of ground water supplies. South Carolina's new ground water use reporting system, for example, was instituted in response to this deficiency, but the accuracy of the data collected under this new law is still uncertain.

Officials of most states in the study area, except Alabama and Tennessee, reported an inadequate number of water quality monitoring wells. Mississippi and Georgia representatives commented that low frequency of monitoring also was a problem. Further water quality monitoring is complicated by the range of potentially hazardous substances that can be measured and the uncertainty about risks at low concentrations. For example, toxic organics, pesticides, and heavy metals may be more of a problem in ground water than surface water because of the slow movement (i.e., less dilution) and limited degradation. Staff of ground water management agencies in Georgia, North Carolina, and South Carolina have expressed their concern that testing for organic compounds may be inadequate. For example, in South Carolina agency staffs are generally too small to perform the large number of analyses needed and a two-month delay on organic contaminant analysis is not uncommon. An increase in manpower is apparently needed to accomplish the inventory of ground water quality, of existing and potential pollution sources, and to establish and maintain a monitoring well network.

Monitoring injection wells by the use of observation wells is a controversial option (Leinesch 1977). Although observation wells constitute the most accurate method for determining movement and changes in the injection aquifer and nearby freshwater aquifers, they present potential disadvantages. While irregularity of geohydrology makes the installation of more than one well necessary if accuracy is to be achieved, but migration of the disposal liquid and contamination of freshwater aquifers may result from both the injection well and from nearby monitoring wells. These wells may provide a channel of escape for the injected wastes if improperly constructed or maintained; therefore drilling a number of monitoring wells can increase the possibility of pollution.

---

[1] States indicating that aquifer characteristics and use data could be improved were: Georgia, Florida, North Carolina, and South Carolina. These states have major dependency on large aquifer systems. Other states have data limitations, especially where aquifers are complex, but the intensity of water use may not create as important management problems.

Even though an extensive monitoring program can provide much ground water information it is virtually impossible to obtain sufficient monitoring data to adequately define ground water quality problems (Roberts and Butler 1983; Murphy 1983; Yoder 1982). The inadequacy derives from three characteristics of ground flow and ground water pollution (Freeze and Cherry 1979):

1. Contamination plumes are normally narrow and of limited depth because ground water flow is laminar rather than turbulent; vertical and horizontal mixing within an aquifer is therefore slight (Figure 4-4).

2. Contaminated aquifers or plumes can be cleaned only at great expense and with less than complete success (Miller 1982).

3. The number of potential pollutants of ground water is very large, with analytical tests for many of these contaminants not yet standardized (Page 1982).

Because contamination plumes are narrow both horizontally and vertically and because potential polluters are numerous and widely dispersed, the number of wells required to ensure complete knowledge of a area-wide ambient water quality in relevant strata would be enormous (Burmaster and Harris 1982; U.S. EPA 1977). As illustrated by figures 4-5 and 4-6 failure to detect the slow-moving, narrow plumes is potentially quite likely (Roberts and Butler 1983). The sampling process must be repeated regularly for a wide variety of pollutants. For these reasons an area-wide ambient ground water quality monitoring program by itself is not likely to provide adequate information adequate to a ground water quality protection program (see chapters 6 and 8).

Ground water quality can also be monitored in or very near supply wells. Monitoring water quality at some distance from supply wells can increase the opportunity to develop alternate supplies or to mitigate the source of pollution and clean the aquifer while there is still sufficient hydrologic distance between the source and the well to attenuate the contaminant (Roberts and Butler 1983). However, using nets of monitoring wells surrounding supply wells to detect ground water quality problems very soon encounters the same problems as does area-wide ambient monitoring--

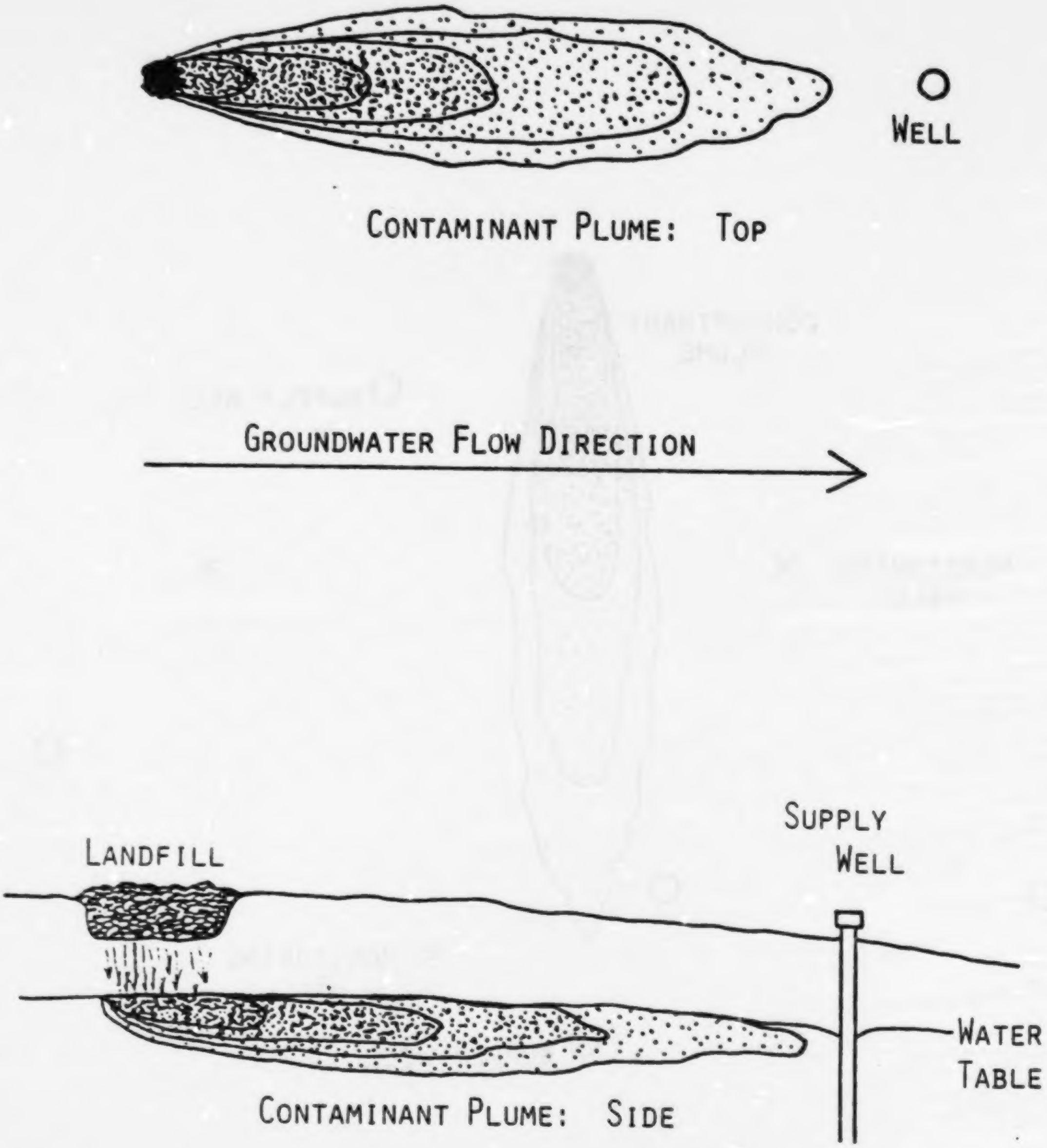


Figure 4-4: Laminar flow resulting in limited contamination spread.

Source: Roberts and Butler 1983.

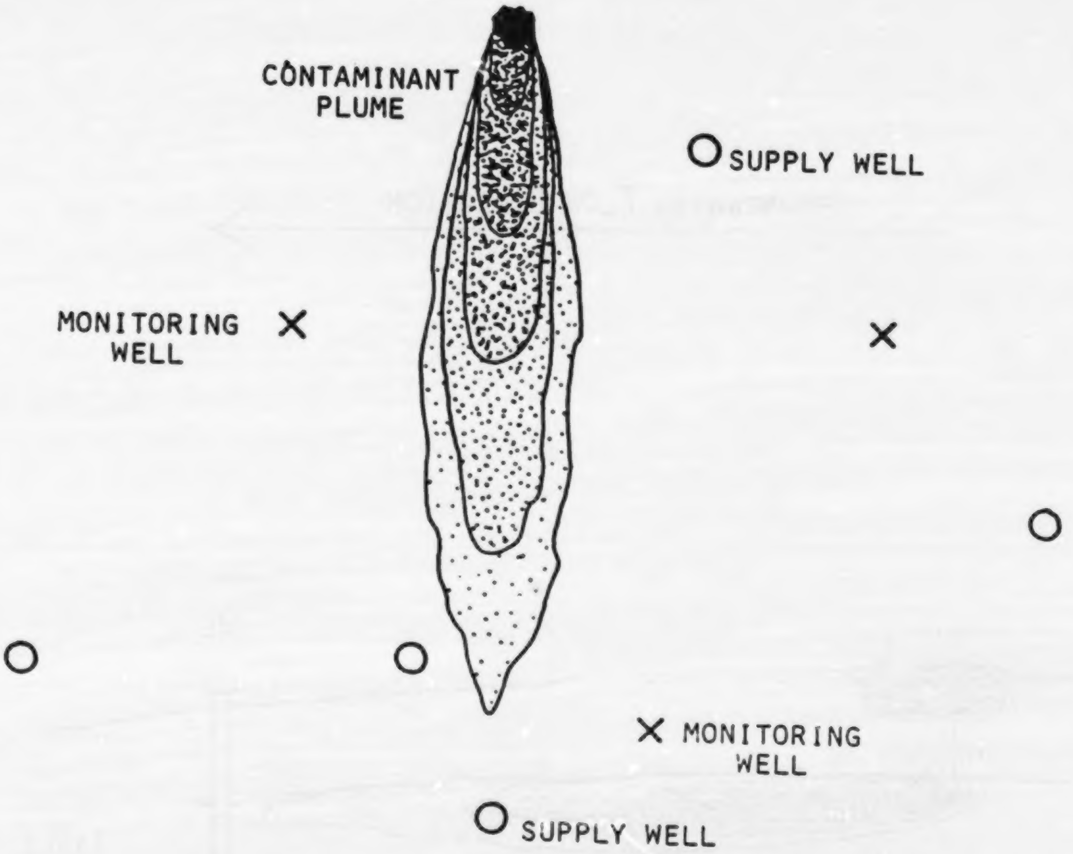


Figure 4-5: Potential for plumes to miss monitoring wells.

Source: Roberts and Butler 1983.

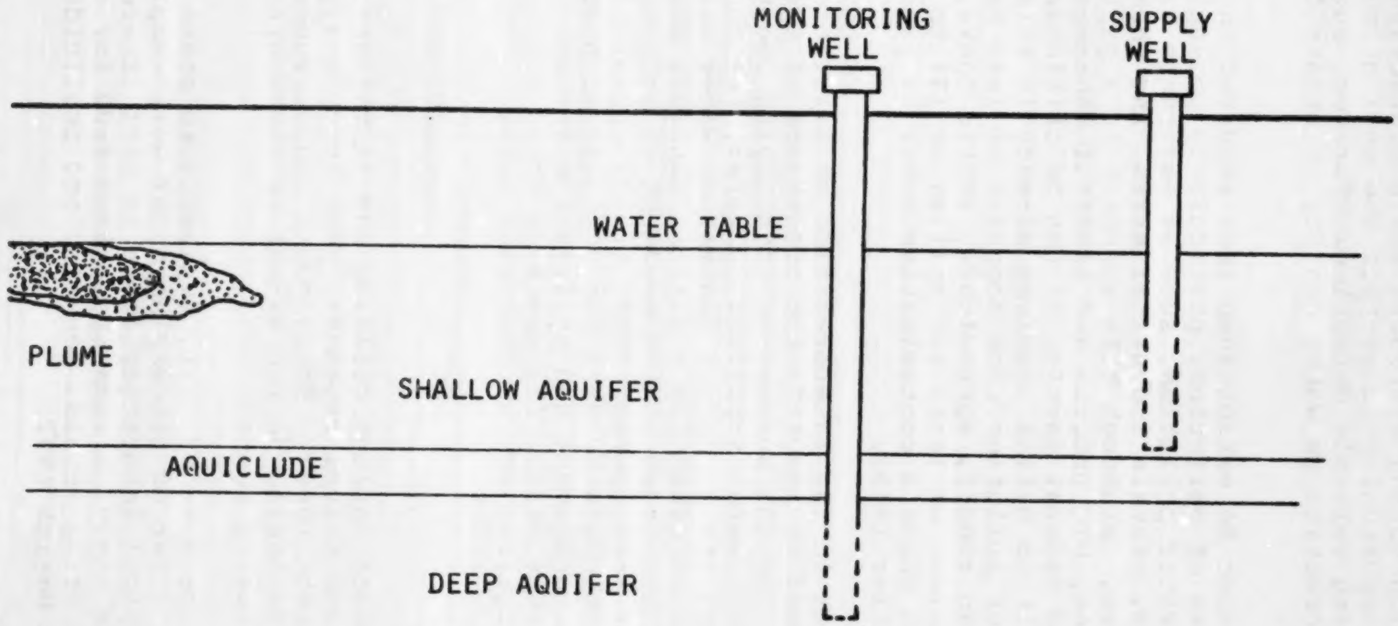


Figure 4-6: Potential for plumes to occur in strata adjacent to monitoring well screens.

Source: Roberts and Butler 1983.

unreliable detection at monitoring distances for a protective approach and inadequate opportunity to protect the well at monitoring distances permitting reliable detection. Further, such an approach provides no information on water quality in strata for location of future wells.

Monitoring nets can also be established (and required in some cases) surrounding sources of pollution, particularly potential major sources of ground water pollution, such as hazardous waste disposal sites, landfills, certain industrial sites, and chemical or fuel storage facilities. Although this approach is a part of hazardous waste facilities, UIC program and landfill management policies at the state and federal levels, it can be criticized because it does little (1) to define problems already in existence; (2) to detect ground water pollution from nonpoint or less hazardous sources such as urban runoff, agriculture, septic tanks, road salting, saltwater intrusion, or leaks and spills; or (3) to predict future contamination where a contamination event is probabilistic (Roberts and Butler 1983).

Limitations also exist in the interpretation of available data. Generally, data can be used to identify the occurrence of the commonly analyzed pollutant for the purpose of identifying locations of health concern in public water supplies. However, the monitoring programs appear inadequate to inform individual water well users of potential pollution risk. In addition, managers would like to anticipate water shortages or the movement of pollutants. The modeling required for anticipating these trends appears inadequate. In short, the problems with data are not just with aquisition, but also with data management and utilization (to be discussed in subsequent sections). The costs of these monitoring programs are also very significant, as discussed below.

B. Economic Constraints

Monitoring network costs include drilling and installation of monitoring wells, staff and travel expenses, laboratory analyses, and data processing (Everett 1980). These costs can be substantial to regulatory agencies, depending on the extent of the monitoring and the method of distributing costs.

Laboratory analyses are a major cost, typically to state agencies monitoring drinking water or processing other well samples. Table 4-16 summarizes typical laboratory costs in 1974 (Everett 1976). A complete sample analysis runs about $500-$800 for standard parameters plus ten heavy metals, phenols, and pesticides (Alabama Dept. of Public Health 1982).

The Florida Department of Regulation has recently estimated costs for ground water monitoring for compliance with their new ground water standards (Florida Dept. of Environmental Regulation,

TABLE 4-16: COST OF WATER SAMPLE ANALYSIS in 1974

Parameter Group	Number of Parameters Measured	Group Rate
Major inorganic chemicals	11	$130
Other inorganic chemicals	5	40
Drinking water standards	13	50
Other trace elements	10	60
Gases	5	30
Insecticides	11	30
Herbicides	3	50
Radioactivity	6	100
Total	64	$490

Source: Everett, 1976

Environmental Impact Statement 1982). Table 4-17 shows the cost breakdowns for various types of monitoring. Well construction costs average $1,200 for the shallow wells required in Florida. The initial sampling and analysis costs are much higher for municipal sewage treatment plants and solid waste sites compared to routine annual sample analysis. This high initial cost is due to the large diversity of parameters initially measured for determination of background levels. Annual well operation and maintenance costs range from $40 to $350 depending on the type of well required.

The cost of monitoring is usually encumbered by well owners for injection wells or hazardous waste disposal sites, or by state and county agencies for drinking water samples. Large scale monitoring programs are funded by the state or by EPA, or the USGS. The reductions in 208 funds and in the federal regional commission studies has significantly reduced support for monitoring programs and data compilation.

TABLE 4-17: MONITORING COSTS FOR POLLUTANT SITES IN FLORIDA

Type of Monitoring	Initial Construction Costs	Sampling and Analysis		Annual Operation and Maintenance
		Initial	Annual	
Municipal sewage treatment plants[a]	$1,200/well	$ 925	$ 200	$140/well
Municipal impoundments[b]	$1.1 million	$874,000	$794,000	$166,000
Industrial sites[c]	$2.0 million	$1.5 million	$1.4 million	$292,000
Mining areas[d]	$ 60,491	$ 48,000	$ 42,000	$ 9,000
Solid waste sites[e]	$1.6 million	$1.2 million	$116,240	$244,000

Source: Florida Dept. of Environmental Regulation, Environmental Impact Statement 1982

[a] Assumes well depth of 40 feet and monitoring for trihalomethanes, number of wells not known.

[b] Costs are for 3,500 municipal impoundments which require 945 wells (2/impoundments/site and 3 wells per site).

[c] Assumes 17 percent of all industrial sites have adequate monitoring. The 1,300 sites require 1,700 wells.

[d] Seventeen phosphate mining areas require 3 wells per site.

[e] Assumes approximately 700 sites, will be monitored only in suspected hot spots.

C. Deficiencies in Coordination and Utilization of Data

Although deficiencies exist in aquiring costly monitoring data, a problem also exists in data management and utilization of available data. Many agencies have expressed concern that current procedures for acquiring, analyzing, storing, and retrieving water data have few, if any, provisions to evaluate data.

There are barriers to utilization of data including, for example, limited dissemination mechanisms for data, or data base incompatability among potential users. Only limited ground water data is now incorporated into predictive management models. Despite their advantages in data coordination, prediction, and potential management application, in few cases have models been a basis for continued data interpretation for decisionmaking. None of the major state agencies responsible for monitoring and data management are using ground water models for management purposes. However, the USGS is using models in cooperation with state geological surveys. Examples of these models include: in Kentucky, four models are being used to study the hydrology of surface mined areas; in Mississippi, a digital model is being used to simulate management of ground water resources in the northeastern part of the state, and ground water level changes as a result of navigation improvement plans on the Yazoo River are being calculated with a model. Pollutant transport models are being applied in Tennessee and Florida; and in Georgia the USGS Regional Aquifer System Analysis studies are making use of ground water models. Whether these modeling approaches will be effective for improving long-term management decisions is uncertain at this time.

Ground water data often is not disseminated effectively. Much of the ground water data developed by state agencies has never been published or reported. As an example, in coastal North Carolina where much of the population depends on ground water, geohydrological data had documented numerous changes in water chemistry and well levels, but with few exceptions this data has never been published (North Carolina Dept. of Natural Resources and Community Development 1982).

Barriers also exist because of incompatible terminology. In many cases the names for geohydrologic units vary among agencies. Often the USGS has contrasting hydrologic designation and units compared to state units of government, even for much of the vast Coastal Plains aquifers. Historic differences in terminology and unit designations persist, so that aggregation of strata and their hydrologic function are not discussed in a compatible manner. These basic technical problems present barriers that could easily be avoided, if only agencies responsible could cooperate to develop consistent designations.

However, the USGS and EPA water resources information systems summarized in Section 5.5.2 attempt to respond to the barriers in information access. Perhaps no other natural resource in the U.S. has more information potentially accessible than for water. In part, the problems of utilization are that these data bases and bibliographic systems simply are not used effectively. However, there also are institutional problems in data utilization--agencies active in acquiring data, or those with the technical expertise, are not the agencies with management or decisionmaking authority.

D. Institutional and Political Constraints

Because ground water problems are not very visible, the public needs to be convinced a problem exists before programs are initiated for adequate ground water monitoring and data management. As described earlier, much of the information on ground water quality is not available to the public, and there is little impetus for legislative or executive branches to take action until a crisis has occurred.

The fragmentation of state agency responsibilities also results in problems if there is lack of information transfer between technically oriented ground water monitoring agencies and those with management responsibilities. In Mississippi, for example, the major data collection agency on ground water characteristics and use is its Geological Survey, but management is authorized in the Board of Health and the Department of Natural Resources. In most states, water availability and use data is in a separate agency from those responsible for water quality. Perhaps the greatest separation of functions is between the USGS and state management agencies. In many states the greatest technical expertise is found in the USGS. Cooperative studies frequently occur between the USGS and state management agencies. Yet when such studies are completed, the management agencies are left without the technical expertise for continuing management responsibilities.

4.5 DRINKING WATER QUALITY

Summary: Ground water provides the major source of drinking water in the Southeast, but numerous violations of drinking water quality standards occur from this source. Problems include limited effectiveness of public notification when violation of standards occurs, insufficient and undertrained manpower, inadequate funding, and minimal enforcement. Synthetic organic compounds likely to adversely affect human health have been detected in drinking water from ground water resources and some organic pollutants (trihalomethanes) can be formed as a result of chlorination. Problems and issues include: (1) the inadequacy of current standards to fully protect drinking water quality and public health; (2) the overlaps and gaps of the multitude of regulatory programs for assuring drinking water quality; and (3) the costs of monitoring and treatment coupled with unknown long-term health effects of low levels of pollutants.

4.5.1 Introduction

Concern over the provision of high quality drinking water for the protection of human health has increased during the last decade. This is due to increased publicity of ground water pollution incidences and to some recent periods of reduced rainfall that have contributed to some availability problems. If ground water contamination becomes more widespread there will be a decreased amount of usable ground water for the growing population of the Southeast and perhaps increased public health problems. The lowering of water levels in wells, toxic waste disposal incidents, and even the drying-up of springs in some parts of the Southeast during recent dry years have increased the concern of many people about the availability and quality of ground water for drinking and other domestic purposes.

Numerous violations of drinking water regulations, most minor, occur annually and an estimated 13,600 community water systems in the U.S. cannot meet Federal drinking water standards without improving their facilities. In the Southeast about 67 percent (in 1970) of the population relies on ground water as a source of drinking water. In rural areas, where treatment and monitoring are less common, about 98 percent of the population depends on ground water. Once an aquifer is polluted restoration methods usually are very costly and are of unproven effectiveness (see Section 6.7). For this reason, prevention of ground water pollution is necessary to ensure the adequacy of drinking water supplies.

The previous sections addressed ground water quality primarily from the point of view of the sources of pollution. In this section the focus is on the provison of high quality drinking water to domestic users. From this perspective the most important concerns are the adequacy of quality standards to protect public health, gaps and overlaps in regulatory approaches, and the costs and effectiveness of control strategies and technologies for meeting quality objectives. In the next section the current status and trends of drinking water quality and regulations in the Southeast are discussed. This is followed by a description of problems and issues related to drinking water quality in the southeastern United States.

4.5.2 Current Status and Trends

In the early 1970's, 66 organic chemicals suspected of posing a risk to human health were discovered in the water supply of New Orleans. This discovery and other concerns gave impetus to the passage of the Safe Drinking Water Act of 1974 (SDWA). Under this act EPA is to establish federal standards and treatment for drinking water, require periodic monitoring and notification of violations, and establish a joint federal-state system for enforcement of the regulations. After extensive review, EPA issued the National Interim Primary Drinking Water Regulations which went into effect June 24, 1977. The contaminants for which maximum allowable contaminant levels have been set are shown in Table 4-18. The primary standards are set to protect the public health and less

TABLE 4-18: NATIONAL INTERIM PRIMARY DRINKING WATER STANDARDS

Constituent	Maximum Contaminant Level[a] (in mg/l unless specified)
Inorganic chemicals	0.05
Arsenic	0.05
Barium	1.00
Cadmium	0.01
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10.00
Selenium	0.01
Silver	0.05
Fluoride	1.4 to 2.4
Organic chemicals turbidity	1 tu up to 5 tu
Coliform bacteria	1/100 ml (mean)
Endrin	0.002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2,4 D	0.1
2,4,5 TP Silvex	0.01
Radionuclides	
Radium 226 and 228 (combined)	5 pCi/l
Gross alpha particle activity	15 pCi/l
Gross beta particle activity	4 mrem/year

mg/l = micrograms per liter
tu = turbidity units
pCi/l = picocuries per liter
mrem = millirem

Source: U.S. Council of Environmental Quality 1979, 156.

[a] Maximum contaminant levels are health goals for substances in drinking water which may have adverse effects on humans.

restrictive secondary standards have been set to protect the public welfare. These secondary standards are intended to protect the aesthetic quality of drinking water, including taste, odor, color, and appearance (U.S. EPA 1979). The act applies to "public" water systems; i.e. those in excess of 15 taps or 25 people.

All of the states in the Southeast exercise primary authority for the enforcement of the SDWA. This means each state has adopted standards and regulations at least as stringent as the federal regulations, including an approved and adequate enforcement program. Generally, several agencies such as a health department, environmental protection agency, or state engineer, share responsibility for drinking water protection (Council of Environmental Quality 1979).

Information on drinking water supply and estimated compliance with the SDWA was obtained from a telephone survey of each state in the study area as described in Section 4.4. Table 4-19 shows the number of public water supply systems for each of these states as reported during the survey. Information was not currently available for Kentucky. One question was related to the compliance of these systems with the drinking water standards and regulations of the SDWA. Agency staff estimated compliance with the standards and with monitoring requirements at high levels, ranging from 75 to 100 percent, with some of the problems being of natural origin. However, representatives of several states were unwilling to estimate compliance.

By contrast, the General Accounting Office (1982) conducted a national review of states' compliance in meeting the Safe Drinking Water Act regulations. Problems found include violations of standards, limited public notification, insufficiently trained manpower, inadequate funding, and minimal enforcement. In fiscal year 1980, one or more violations occurred in 28,000 of the nation's 65,000 public water systems (43%). EPA estimates that at least one drinking water quality standard cannot be met without improvements in facilities by 13,600 community water systems. Seven states, none in the Southeast study area, were examined in detail and similar trends were found.

Of the 146,000 nationwide violations recorded, the public was notified, as required by EPA regulation, in only 16,000 cases (11 percent). EPA's own enforcement actions to bring systems into compliance have been found to range from none to minimal and were not timely (General Accounting Office 1982). Improved enforcement efforts include a efforts include policy in June 1980, for bringing into compliance smaller public drinking water supply systems. EPA has also solicited public comments and is currently studying ways to improve enforcement, public notification requirements, and other aspects of its drinking water program (General Accounting Office 1982).

Cornell University researchers found in an analysis of drinking water in 7,654 rural households (primarily private wells) that 63 percent were contaminated and possibly unsafe. Most serious problems included bacterial contamination in 29 percent of the homes. Lead, mercury, and selenium were also found in excessive levels in some supplies. Many of the sources studied were nonpublic systems (i.e. less than 15 taps and 25 persons) and hence are not covered by the Safe Drinking Water Act (Ecolibrium 1982).

TABLE 4-19: PUBLIC WATER SUPPLY SYSTEMS SURVEY OF THE SOUTHEAST

	Number of Public Water Supply Systems[a]			
State	Community	Noncommunity	Total	Estimated Compliance (percent)
Alabama	-	-	3,000	100
Florida	2,456	2,885	5,341[b]	75[e]
Georgia	1,350	1,400	2,750	- [f]
Kentucky	NA	NA	NA	NA
Mississippi	1,300	2,300	3,600	- [g]
North Carolina	-	-	1,000,000[c]	NA
South Carolina	1,000	1,250	2,250[d]	- [h]
Tennessee	350	900	1,250	NA

NA = Not Available

Source: Telephone survey conducted during August and September 1982. See Section 4.4.1 and Appendix B.

[a] Each system has 1 or more wells, however, most systems (over 80 percent) have less than 4 wells.

[b] Individual wells are used for multiple purposes: e.g., 90 percent are used for drinking water supplies, 80 percent are used for industrial supply, and 50 percent are used for irrigation.

[c] This is the estimated number of wells used for drinking water supply.

[d] 100 of the systems use surface supplies, all systems use from 1 to 22 wells each.

[e] Problems in the 25 percent of the systems reportedly not in compliance include bacterial contamination and high pesticides, radioactivity, and fluoride levels.

[f] Only 12 sites in 6 counties were out of compliance in Georgia in August, 1982.

[g] Bacterial contamination and brine intrusion have caused some noncompliance. About 20 percent of the systems are in noncompliance as a result of brine intrusions.

[h] About 2 percent of the systems are out of compliance due to high bacterial and nitrate levels and about 3 percent have naturally high radioactivity levels.

[i] All noncommunity systems are in compliance in Tennessee but the status of community systems is not available.

Surveys of the occurrence of organic pollutants in drinking water are being conducted by EPA. By March 1980, more than 8,000 chemical measurements of volatile organic compounds had been made nationally from hundreds of wells. Data for six of the study states at that time is shown in Table 4-20.[1] As shown, some of these toxic organic compounds were detected in up to 50 percent of the wells tested. Concentrations were generally found to be at low levels (less than 1 milligram per liter), but still of potential health significance. These surveys indicate that on a national basis a significant number of water supplies using ground water, as well as surface waters, contain some volatile organic chemicals. About 26% of ground water supplies have been shown to contain some synthetic organic chemicals (Mlay 1982) and the concentrations found are often much higher than those reported in surface waters. Volatile organic chemicals were shown for the nation as a whole to be present in about 29 percent of water supply systems serving more than 10,000 people, and in about 17 percent for those serving less than 10,000 people (Ground Water Monitoring Review 1983). Most systems had very low levels of contamination (usually in parts per billion) (Federal Register 1982b).

Fourteen synthetic organic compounds most commonly detected nationally in ground water from these studies are shown in Table 4-21. It has been found that high concentrations of many synthetic organic chemicals, when ingested in food and drinking water, can cause acute (immediate) health problems such as nausea and dizziness. Long-term chronic effects are less clear, but some have been shown to be carcinogenic in laboratory animals. This includes a widely used solvent, trichloroethylene, which is also a component of products used to clean septic tanks (Council on Environmental Quality 1979 and 1980).

EPA has stated its intent to regulate the human exposure to high levels of some of the chemicals listed in Table 4-21 and may issue regulations for all fourteen if appropriate. The EPA has issued regulations (MCL's) limiting the allowable level (0.10 mg/l) in drinking water of total trihalomethanes (TTHM's) which have been found to be of particular health concern. TTHM's can be formed as a result of chlorination when the water contains low levels of natural organic compounds such as humic and fulvic acids. For a system with total TTHM levels above the MCL, best treatment methods may be required, including the use of alternative disinfection methods, improved clarification to reduce TTHM precursors, and seasonal or intermittent powdered activated carbon. Previously proposed treatment methods that were controversial, granular activated carbon and biologically activated carbon, were not included (Federal Register 1982c). Permissible levels for other organic chemicals found in drinking water have not been issued because of

---

[1] This analysis by EPA is continuing but additional findings are not available as of early 1983.

TABLE 4-20: SELECTED ORGANIC COMPOUNDS FOUND IN GROUND WATER (1980)

Chemical	Percentage of Wells with Chemical Present					
	Alabama (80)[a]	Florida (329)[a]	Kentucky (22)[a]	North Carolina (44)[a]	South Carolina (4)[a]	Tennessee (50)[a]
Trichloroethylene	10	NM	0	18	0	14
Carbon tetrachloride	0	50	5	0	0	8
Tetrachloroethylene	4	20	0	5	0	2
1,1,1-Trichloroethane	10	15	0	2	0	26
1,2-Dichloroethane	3	15	0	7	25	8
1,1-Dichloroethane	8	36	0	14	0	26
Dichloroethylenes	10	38	0	45	50	26
Methylene chloride	0	1	NM	18	0	8
Vinyl chloride	1	16	0	34	0	6

NM = No measurements taken.

Source: U.S. Council of Environmental Quality 1980, 94.

[a] Number of wells tested.

TABLE 4-21: SYNTHETIC ORGANIC CHEMICALS MOST COMMONLY DETECTED IN GROUND WATERS

Trichloroethylene
Tetrachloroethylene
Carbon Tetrachloride
1,1,1-Trichloroethane
1,2-Dichloroethane
Vinyl chloride
Methylene chloride

Benzene
Chlorobenzene
Dichlorobenzene (5)
Trichlorobenzene (1)
1,1-dichloroethylene
cis-1,2-dichloroethylene
Trans-1,2-dichloroethylene

Source: Federal Register 1982b.

the difficulties in establishing relationships with human health effcts (Council on Environmental Quality 1979).

The Underground Injection Control (UIC) program, which is included in the Safe Drinking Water Act (SWDA), establishes a national program to prevent and control underground injections which endanger drinking water.[1] The Act requires EPA to:

- Publish minimum national requirements for effective state UIC programs;
- List states that need UIC programs;
- Make grants to states for developing and implementing UIC programs;
- Review proposed state programs and approve or disapprove them; and
- Promulgate and enforce UIC programs in listed states if the state chooses not to participate or does not develop and operate an approved program.

---

[1] EPA proposed a set of UIC regulations for public comment in the August 31, 1976 Federal Register. After many comments were received, the EPA revised the regulations, and added several new requirements. The UIC program was finalized, published in the June 24, 1980 Federal Register and subsequently became Part 146, Title 40, Code of Federal Regulations, and became effective on July 18, 1980. Compliance with the regulations were to be met within 120 days (April 20, 1981), with the possibility of an additional 120 days extension (January 15, 1982). Minor revisions of the UIC Rules and Regulations are described in the February 3, 1982 Federal Register.

Congress apparently intended the UIC program to protect not only the ground water which already serves as a source of drinking water but also the ground water that could serve as a source of drinking water in the future. Therefore, EPA's regulations to establish the UIC program propose that all aquifers or portions of aquifers currently serving as drinking water sources be designated for protection. Other aquifers capable of yielding water containing 10,000 or fewer milligrams per liter of total dissolved solids should also be designated. However, not all underground water sources were to be recognized as suitable for providing drinking water. Some aquifers might be used for producing minerals, oil and gas, or geothermal energy. Others are so contaminated or located in such a manner that recovery of water for drinking purposes might be economically impractical or technologically impossible. Such sources might not be designated for protection unless they already serve as sources of drinking water.

To implement its proposed regulations, EPA categorized well injection activities into five classes:

- Class I wells are those used to inject industrial, nuclear, and municipal wastes beneath the deepest stratum containing an underground drinking water source;
- Class II wells are used to dispose of fluids which are brought to the surface in connection with oil and gas production, to inject fluids for the enhanced recovery or oil and gas, or to store hydrocarbons;
- Class III wells are those used to inject fluids for the solution mining of minerals, for in-situ gasification of oil shale and coal, and to recover geothermal energy;
- Class IV wells are those used by generators of hazardous wastes or by owners and operators of hazardous waste management facilities to inject into or above strata that contain underground drinking water sources; and
- Class V wells include all wells not incorporated in Classes I-IV. Typical examples of such wells are recharge wells and air conditioning return flow wells.

Each class has specific regulations that must be followed. The regulations range from casing and cementing requirements to periodic demonstrations of mechanical integrity. There are to be no new Class IV wells authorized or permitted, and operators of currently used Class IV wells must perform weekly monitoring of the impact of injections on drinking water.

The use of permits is required, and the permanent and temporary rules will differ depending on the particular situation. These regulations are minimum requirements, and states may choose to adopt stricter standards. Permits are required for owners/operators of Class I, Class II (except existing enhanced recovery and existing hydrocarbon storage), and Class III wells. New wells (those that begin to inject after the effective date of a program in a state) must be authorized by a permit before injection may begin.

Of the eight states in the Southeast region, two (Kentucky and Tennessee) have no current plans to initiate a state UIC program. The other six states are, or have submitted UIC plans to the EPA according to the following schedule:

Alabama--submitted May, 1982;
Florida--submitted January, 1982;
Georgia--to be submitted January, 1983;
Mississippi--to be submitted November, 1982;
North Carolina--submitted July, 1982; and
South Carolina--"in progress."

The number of injection wells in the region is in excess of 14,300. The state-by-state breakdown is shown in Table 4-22.

4.5.3 Problems and Issues

Three main problems and issues related to the provision of adequate quality drinking water are discussed in this section. These are: (1) the adequacy of current standards and regulations to protect drinking water quality and public health; (2) the adequacy of current regulations to protect drinking water quality; and (3) the costs of monitoring and treatment. While each of these problems and issues is national in scope, where data allows the focus of the discussion is on their relevance to current and anticipated conditions in the Southeast.

A. Adequacy of Drinking Water Quality Standards

As a result of the reported occurrence of synthetic organic compounds in drinking water, questions have been raised over the adequacy of current drinking standards and regulations to protect public health. This is a topic of current concern within EPA (Federal Register 1982b and 1982c) which may not be resolved in the near future. To date more than 700 chemicals have been identified in drinking water supplies yet only 16 maximum contanimant levels have been established under the SDWA. Few standards and regulations exist at any governmental level limiting these 700 chemicals in drinking water (Singer 1982).

The difficulty in establishing standards and regulations for these synthetic organic chemicals stems from the uncertain link between synthetic organic chemicals found in drinking water and

TABLE 4-22: INJECTION WELLS IN THE SOUTHEAST[a]
(Number)

State	Class of Wells				
	I	II	III	IV	V
Alabama	2	163	9	-	200+
Florida	50	100	-	3	6,900 (return cooling)
Georgia	-	-	-	-	4 (return cooling)
Kentucky[b]	2	6,000	-	2	200
Mississippi	5	-	-	-	-
North Carolina	-	-	-	-	200 (heat pump)
South Carolina	-	-	-	-	850 (heat pump)
Tennessee	9	<20	-	-	-

[a] Based on an informal telephone survey of states conducted in August-September, 1982 (see Section 4.4.1 and Appendix B). Notice that there are five Class IV wells (injecting hazardous waste into or above strata that contain underground drinking water sources).

[b] There are about 14,000 oil and gas wells in Kentucky. Of these about 6000 are apparently used for water flooding, 335 Class "II-R" wells exist that are salt water disposal wells (Dinger 1985).

increased human cancer rates or other health effects. EPA relies on animal studies, clinical studies, and epidemiology to estimate the health risk of chemicals on drinking water and; to date, the evidence is not strong. Some have taken the position that at levels commonly found in drinking water synthetic organic chemicals have not been shown to cause cancer in animals (Pendygraft, Schlegel and Huston 1982). Yet at higher levels some of these chemicals have produced cancer in laboratory animals in some studies. The long-term effects on humans of exposure to low levels of synthetic organic chemicals is poorly known. EPA has taken a conservative position by proposing treatment to remove those chemicals that may be a health risk. However, the treatment methods are costly, as is discussed below, and some feel disproportionate to the health risks that may be involved.

B. Adequacy of the Regulatory Program

A second issue related to drinking water quality is the adequacy of the Safe Drinking Water Act to protect ground water supplies and existing gaps and overlaps in other ground water quality regulations. The SDWA administered by EPA is the primary federal legislation protecting drinking water quality, but other laws also apply to the protection of drinking water. These include the Clean Water Act, the Resource Conservation and Recovery Act, the Toxic Substances Control Act administered by EPA, and the Surface Mining Control and Reclamation Act administered by the Department of Interior including the U.S. Geological Survey. Taken together, these laws overlap, there is some duplication of effort and there are some gaps in coverage even when considering state efforts (Council on Environmental Quality 1980). For example, as discussed above only a limited number of pollutants are addressed by the SDWA regulations and small ("nonpublic") drinking water systems are not regulated. This means that no provisions for small water supply systems and individual water wells are included in the law. However, these supplies are an important source of drinking water in rural areas. The Clean Water Act (CWA) provides for general environmental water quality, including some provisions for the protection of ground water, but the Act does not provide direct protection for drinking water quality. The Resource Conservation and Recovery Act (RCRA) includes provisions to protect surface and ground water quality from the use and disposal of certain pollutants but does not directly regulate drinking water quality. The most critical cases of ground water (and surface water) pollution are being addressed by the Resource Conservation and Recovery Act (RCRA) but there are limitations to this program (see Section 4.2) and numerous smaller cases of pollution that potentially threaten many southeastern water users are not included (Giese 1982).

Finally, although the UIC program provides an initial comprehensive program to control subsurface discharge of wastes, as currently instituted, most states are controlling Class II wells (primarily brine injection wells) through an oil and gas commission, whose primary mission is the promotion of oil and gas development. Serious consideration should be given for shifting such control to a health or environmental enforcement agency to help assure environmental protection goals (see also Section 4.3.3). In addition, many of the problems occur in rural areas, away from state-level staff and enforcement officers who must implement the program. By providing local control to the governments that are in charge of their municipal or rural water supply systems, a direct linkage between disturbances to ground water and responsible government service can possibly be achieved.

Also important are the "sole source aquifer" provisions of the SDWA. In areas where the drinking water comes primarily from a single aquifer, special sole source aquifer designation and protection regulations were established by the SDWA. This provision is directed toward prevention of ground water pollution to minimize expensive treatment later. While several sole source aquifers have been designated, the effectivenes of that designation is limited (see Section 4.6). According to some, a more restrictive regulation may be desirable (see, for example, Singer 1982). During 1982 several amendments to the Safe Drinking Water Act were introduced including some to strengthen the sole source aquifer provision; for example, Senate Bill 2131 would provide increased funding and additional authority to the states to regulate activities around sole source aquifers.

In summary, the states generally do not have sufficient resources to adequately regulate drinking water quality (U.S. General Accounting Office 1982). The most effective program to provide good quality drinking water is to prevent pollution by regulating the discharge and disposal of pollutants. This is especially important since aquifer cleanup is very costly and often only partially effective. As indicated, preventing ground water pollution involves the provisions of many overlapping laws and regulations. The Safe Drinking Water Act by itself does not include provisions to prevent pollution (except for sole source aquifers) and EPA must coordinate its efforts under several laws to be most effective.

C. Costs of Monitoring and Treatment

A third problem is the high cost of treating drinking water to reduce levels of synthetic organic chemicals and total trihalomethanes (TTHM's). The costs of drinking water monitoring and analysis can also be high (at least $200 per sample for some organic chemicals). Costs for treating specific pollutants by alternative technologies have been estimated. For example, Table 4-23 shows preliminary cost estimates for two types of aeration and GAC absorption for the treatment of trichloroethylene. (Each of the treatment technologies would remove other volatile organics if present.) Per capita costs depend on system size and percent treatment but, in general, packed tower aeration was found to be least costly (Federal Register 1982b). The relative effectiveness of these treatment methods vary depending on the chemical characteristics of the pollutants to be treated (Love and Eilers 1982).

As noted earlier, granular activated carbon or biologically activated carbon were not included in recent EPA regulations to treat TTHM's. This is due at least partly to the controversy over the costs of these methods and the availability of less costly and equally effective treatment methods. Alternative chlorination methods including the use of chloramines, chloride dioxide, changing the point of clorination or using certain chlorine substitutes are allowed in the recent regulations (Federal Register 1982c) and may be adequate in many cases to bring a facility into compliance with TTHM standards. The use of chloramines is being considered in Dade County, Florida (Day and Zimmerman, Inc. 1982). However,

TABLE 4-23: SUMMARY OF PRELIMINARY COSTS FOR CONTROLLING TCE IN DRINKING WATER[a]

Treatment Process	Population Served					
	100-499	1,000-2,499	10,000-24,999	100-499	1,000-2,499	10,000-24,999
	90% Removal			99% Removal		
Aeration--Packed Tower:						
Capital expenditures[b,c]	27-40.5	103.5-134	367.5-524	28.0-42.5	155-253	416-649
Revenue requirements per year[b,c]	5-7	17-21.5	75.5-96	5.5-8	19.5-26	88.5-117
Cost per 1,000 gallon ($)[c]	0.53-0.74	0.21-0.27	0.06-0.10	0.58-0.8	0.25-0.33	0.09-0.12
Increase in monthly residential costs ($)[d]	4.65-6.49	2.04-2.58	0.72-0.92	5.11-7.43	2.34-12	0.85-1.13
Aeration--Diffused Air:						
Capital expenditures[b]	55.0	197.5	962.0	67	276.5	1,362
Revenue requirements per year[b]	10.5	42.0	252.0	14.5	68.5	399
Cost per 1,000 gallons ($)	1.11	0.53	0.26	1.53	0.86	0.41
Increase in monthly residential costs ($)[d]	9.76	5.04	2.41	13.48	8.23	3.81
Absorption--GAC:						
Capital expenditures[b]	82.0	344.0	741.0	82	344	741
Revenue requirements per year[b]	14.5	63.5	212.5	15	65.5	242.5
Cost per 1,000 gallons ($)	1.53	0.79	0.22	1.58	0.82	0.25
Increase in monthly residential costs ($)[d]	13.48	7.62	2.03	13.95	7.87	2.32

Source: Federal Register 1982b, 47.

[a] 1981 dollars. Concentration of TCE before treatment is 500 micrograms/liter.

[b] Costs are presented in thousands of dollars.

[c] The low end of the range represents costs for fiberglass reinforced plastic towers with plastic media, and no housing requirements, while the high end of the range represents costs for carbon steel towers with ceramic media, with housing of the towers included.

[d] Residential costs for average family of three were projected by Temple, Baker, and Sloane, Inc. These calculations assume that costs are directed among residents, commercial, and industrial users based on a survey of historic billing allocations.

alternative chlorination methods will not help reduce the presence of other trace organics.

4.6 INSTITUTIONAL AND MANAGEMENT ISSUES

Summary: In many respects ground water is the last major area of environmental quality to be protected. Although several pieces of federal legislation address segments of ground water protection, many ambiguities exist about the purpose and scope of this legislation and there are important aspects of ground water protection which are omitted. State governments are likely to continue to have primary responsibility for managing ground water resources. However, for most southeastern states, ground water quality protection has not been a major item on the public agenda; thus, few states have well-developed protection or management strategies. As states begin to develop legal and regulatory mechanisms for protecting ground water, administration and implementation of these mechanisms will present several difficulties. Local governments have a significant potential capacity to manage ground water through zoning and planning functions, yet these powers have been exercised sparingly throughout most of the study area.

4.6.1 Inadequate Federal Legislation

Federal legislation designed specifically to protect ground water has not been developed, in contrast to surface water, air, and land resources. There are two general explanations for this situation. First, management of ground water resources has traditionally been a state responsibility. Because state governments have not taken a strong regulatory position, ground water law has favored the autonomy of the individual user. In some states basic doctrines of negligence and nuisance were applied to ground water, but they have had very limited value in controlling ground water pollution (Tripp and Jaffe 1979, 26). In the Southeast, ground water has traditionally been viewed as an area where governmental involvement, at any level, should be minimized. Second, ground water protection has not been a major issue on the public agenda--water resources generally have been abundant and many ground water quality problems are less visible than surface water problems. Ground water pollution has few aesthetic impacts and there have been few major events or catastrophes to focus public attention.

As indicated in Table 4-24, several federal laws partially affect ground water. The two most significant of these are the SDWA and the RCRA. The SDWA provides standards to protect public drinking water, regulates pollution from deep well injection through the UIC program, and establishes the "sole source aquifer provision" allowing for some land use controls of recharge zones of aquifers

TABLE 4-24: FEDERAL LEGISLATION PROTECTING GROUND WATER QUALITY

Law	Scope of Ground Water Provisions	Weakness Related To Ground Water Protection
SDWA, 1974	Intended to ensure the quality of publicly supplied drinking water. EPA has established standards (maximum contaminate levels) for 10 inorganic substances, 6 pesticides, turbidity and microbiological and radioactive contaminants. The UIC program regulates one point source of ground water pollution (deep well injection) and the "sole source aquifer" provisison protects the recharge zone of aquifers which are the sole or principal source of drinking water for an area.	• Only one sole source aquifer has been designated in Region 4. • The act disregards the use of environmental criteria for protecting ground water. • Protecting underground drinking water supplies from "endangerment" has been criticized as too lenient; a non-degradation policy has been recommended by some interests.
RCRA, 1976	Provides a framework for controlling land disposal of municipal wastes and the generation, treatment, storage and disposal of hazardous wastes. "Disposal" is defined to explicitly recognize the threat to ground water contamination. Facilities above aquifers that are underground drinking water sources must not endanger ground water quality. Recharge zones of sole source aquifers are given special protective status.	• The act does not provide for the development of water quality standards. • Ground water is defined solely in terms of drinking water source--degradation harmful to other values such as ecological are not recognized.
FWPCA, 1972 and CWA, 1977	EPA given authority over surface and ground water. Sections granting specific federal authority over ground water are: (1) 208 area-wide planning programs; (2) 303 water quality standards and implementation plans; and (3) the National Pollution Discharge Elimination System (NPDES).	• It is not clear that the regulatory provisions of the act apply to ground waters since they may not be "navigable". • EPA has not actively tried to regulate land and subsurface disposal under these acts, or to regulate discharge from publicly owned treatment plants. • EPA has not attempted to develop ground water quality standards. • Regulations actually may increase ground water pollution by encouraging diversion of surface pollutants to the ground.
TSCA, 1976	Enables EPA to regulate the manufacture, use, and disposal of toxic pollutants. While it is not directly intended for ground water protection, it does recognize disposal problems as a reason to regulate a substance, if it poses "unreasonable risks".	• EPA's regulatory authority is limited and key terms such as "unreasonable risks" are not clearly defined.
SMCRA, 1977	Provides for limited ground water protection in areas of heavy surface mining. U.S. Dept. of Interior has authority to issue operating permits, mining and reclmation plans, and reclamation mining and reclamation plans, and reclamation bonds. It provides for the prevention of chemical contamination and hydrological disruption of ground water.	• Does not have comparable coverage for all minerals.

that are sole or primary sources of drinking water.[1] RCRA provides a framework for controlling land disposal of municipal wastes and the generation, treatment, storage, and disposal of hazardous wastes. The Act also reaffirms that recharge zones of sole source aquifers are to have special protective status (Tripp and Jaffe 1979, 22).[2]

Several questions can be raised about this legislation and the appropriateness of a strong federal role in ground water protection. The most basic criticism appears to be that none of this legislation is specifically targeted toward ground water; thus, ground water quality standards to protect resources have not been developed (Tripp and Jaffe 1979; Giese 1982; Horne 1982), and no clear goals for ground water protection have been established. Several secondary criticisms have been made, including: (1) only human health criteria are used; environmental and ecological values are not recognized as criteria for protecting ground water; (2) key terms such as "unreasonable risk" (TSCA) and "endangerment" (RCRA, SDWA) are unclear; and (3) the Federal Water Pollution Control Act (FWPCA) may actually increase threats to ground water by encouraging the diversion of surface pollutants to ground waters.

In addition, several uncertainties exist about the legal/regulatory structure that make it more difficult to manage emerging ground water problems. Among the most significant of these uncertainties is intergovernmental coordination, particularly the relative degree of federal and state responsibility. Current trends in decentralization and reduced emphasis on federal regulatory approaches suggest that state and local governments are likely to be the primary factors in ground water protection. However, EPA has developed a proposed ground water protection strategy (U.S. EPA 1980). If this strategy is ultimately adopted,[3] it may include elements of a centralized regulatory structure, such as a framework for a classificaiton system (see Chapter 6). The current uncertainty about whether and in what form this strategy may be adopted makes it difficult for states to develop their own ground water protection strategies, which later could be superseded to some degree by federal regulations. Based on the history of state-federal relations in surface water and air quality protection, these intergovernmental issues may be the most difficult barriers to the development of effective and efficient regulatory approaches (Hall, Ballard, White 1978; Science and Public Policy 1981).

---

[1] The sole source provision only affects areas where federal projects are involved--private developments are not subject to land use controls. In addition, no federally assisted project in a sole source area has been permanently halted.

[2] The implications of RCRA for ground water protection are elaborated in the discussion of waste disposal in Section 5.2 of this chapter.

[3] The strategy, originally developed in 1980, and recommended by EPA in 1983 has been tabled by the cabinet council on Natural Resources and Environment.

Elements of EPA's proposed ground water protection strategy were intended to: (1) increase state and local institutional capacity to manage ground water; (2) improve the implementation of existing laws affecting ground water; (3) improve the evaluation of ground water quality; and (4) develop a process in which state and local decisionmakers and the public can set priorities for protecting ground water. Specific management elements of the proposed strategy included:

- A classification system to provide different levels of protection for different areas;
- State development of ground water protection strategies that will identify specific programs to meet the stated goals;
- Development of minimum national requirements (standards) for high priority problems, such as highly toxic chemicals and pesticides; and
- Administrative action by EPA to coordinate federal programs and develop state/EPA agreements.

One of the most controversial elements of the proposed strategy was the concept of ground water classification. The premise of a classification system is that different levels of protection should be provided to ground water according to several factors that vary by location--including present and projected uses, current quality, yield, availability of alternative supplies, and vulnerability. The classification process would identify high priority ground water areas for high levels of protection and assist in identifying those areas least environmentally sensitive for siting facilities that are potential polluters (see Section 6.6).

It has been suggested that this classification approach has too many uncertainties and should not be undertaken until the consequences are reasonably well understood (Howells 1981). Until then, it has been argued that national and state policies should provide for the protection of all high-quality and sole source ground waters irrespective of projected uses. Objections to the classification approach include: (1) uncertainty about future uses; (2) the complexity of applying this concept; (3) practical implementation questions such as controlling land uses which affect multiple aquifers (Howells 1981); and (4) the cost of developing and implementing such broad regulatory mechanisms. Elaboration of the classification system for dealing with ground water pollution can be found in Chapter 6.

4.6.2 State Approaches to Ground Water Protection

State regulation of ground water pollution has some parallels to federal legislation--state programs generally are directed at pieces of the problem, such as specific point source discharges or hazardous wastes. Except for Florida and North Carolina, no systematic approaches have been developed in the Southeast. This largely reflects the fact that ground water is not a major problem in many areas and, where it is a problem, it has only recently become a concern. Thus, little public or political support for protection has developed to date.

This does not imply that ground water quality problems are unrecognized. In fact, a general level of awareness and concern does exist among many state geologists, hydrologists, and middle-level administrators (see Warman 1981, 1-73). However, ground water has been slow to develop as a priority public problem because of its historical abundance and because of lack of awareness among the general public, policymakers, and high level administrators (Peek 1981, 57). According to a member of the North Carolina Department of Natural Resources and Community Development, ground water receives little attention compared to surface water and is "largely taken for granted" (Peek 1981, 42).

All states of Region 4 have developed some mechanisms for regulating ground water quality. Table 4-25 summarizes ground water programs, based on several recent reviews (U.S. WRC 1981; Wickersham 1981; and Warman 1981). Based on these data, all states of the Southeast have programs to limit some of the most common sources of ground water contamination, such as deep well injection of industrial wastes, and landfills. A few states have regulated oil and gas brine (Georgia, Mississippi, North Carolina) and salt water intrusion (Florida, North Carolina). Most of the states have not adopted water quality standards, classification systems, or land use controls (Alabama, Kentucky, Mississippi, South Carolina, and Tennessee).

South Carolina and Georgia have initiated broad progams to protect ground water and Florida and North Carolina have developed approaches to ground water protection that include regulation of pollution sources, water quality standards, and a classification system. In Florida, the Department of Environmental Regulation has classified aquifers and issued water quality standards to protect drinking water supplies. Local governments are authorized to use their zoning power to restrict activities over recharge zones. Dade County has exercised this authority and Broward and Palm Beach counties are developing control measures.

TABLE 4-25: STATE GROUND WATER PROTECTION STRATEGIES

State	Sources of Contamination Regulated				Quality Standards			Classification System		Land Use Controls[a]	
	Deep Well Injection (Industrial Waste)	Land Fills	Oil/ Gas Brine	Salt Water Intrusion	Drinking Water[b]	Water Quality Standards[c]	Well Standards[d]	In Place	Being Developed	In Place	Being Developed
Alabama	X	X	X								
Florida	X	X		X	X	X	X	X		X	
Georgia	X	X	X		X		X				
Kentucky		X							X		
Mississippi	X	X	X								
North Carolina	X	X	X	X		X		X			
South Carolina	X	X				X		X			
Tennessee	X	X									

Sources: Adapted from Wickersham 1981; U.S. Water Resources Council 1981; and Warman 1981.

[a] Land use controls are typically a local responsibility. See section 4.6.4 below.

[b] This refers to whether states have developed their own standards to protect public health, separate from (in addition to) federal standards under the SDWA.

[c] This describes whether water quality standards have been developed to protect aquifers, based either on nondegradation or on specific uses (classification).

[d] This identifies whether states have put restrictions on wells in order to protect ground water quality. These include limitations on withdrawal to prevent salt water intrusion or excessive lowering of the water table, interference with existing water sources, or minimum well spacing.

Since 1978, North Carolina has been developing a ground water protection strategy based on three components--research, management, and technical support. The research program is intended to provide a comprehensive evaluation of the state's ground waters, including extensive hydrological and geophysical studies, development of local and regional management plans and reports, classification studies, and research assistance to local governments. The management part of the program has the following components (Peek 1981, 42-44):

- Develop and implement standards for ground water use and quality protection;
- Ground water quality classification;
- Monitoring of ground water levels, use, and quality;
- Inventory of pollution sources;
- Management of underground injection;
- Issuance of ground water permits; and
- Investigation of emergency episodes.

4.6.3 The Need for State Management Capacity

While it is clear that most states have taken a piecemeal approach to ground water management, there appears to be very little agreement about what a comprehensive strategy should be (Bartlett 1979; Dawson 1979).[1] Most states in the Southeast already face, or are likely to face, a common set of threats to ground water-e.g., salt water intrusion, contamination from hazardous wastes, landfills, lagoons, deep well injection, etc. Yet variations in the degree of these threats and the characteristics of water resources will mean that the approach of each state will be somewhat unique. For example, water problems in Florida are conditioned by the virtual lack of distinction between surface and ground water, porosity of the soil, and nearly total dependence on direct recharge by rainfall rather than from surface waters. This will require a management approach different from that needed in South Carolina, where recharge areas are less well-defined and ground water characteristics are distinctively different in the Piedmont area than in the coastal plain.

---

[1] For examples of approaches to management, see Giese (1982) and Tripp and Jaffe (1979).

Recognizing that both similarities and differences exist in state resources and problems, Table 4-26 indicates the major elements which could be included in a comprehensive ground water management program. The purpose of this table is to suggest that there are many elements to a management system. All of these components will not be required in every state. However, this does provide a checklist which can be used to identify current capacity and to anticipate future management needs.

Ground water management begins with an awareness that problems exist and an understanding of how problems could affect both growth and environmental quality in a state. This includes two central questions: whether ground water has been placed on the political agenda, including attention by legislatures and governors, formation of special commissions, etc., and the extent of public discussion and interest in ground water, including the general public and specialized publics such as interest groups, industries, etc. Once awareness and interest have developed, a second management need is to develop informational capacity. This includes characteristics of ground water systems, identification of potential threats to ground water quality such as hazardous wastes or future growth of septic tank usage, development of monitoring capacity, and development of state supported research programs. Most southeastern states are now developing water quality information systems, often in conjunction with the USGS.

While awareness and expertise may be prerequisites to developing a management capacity, the effectiveness of state programs is likely to depend on the development of standards and goals to protect and preserve ground water, the ability to handle emergencies such as contamination of drinking water supplies, and the development of administrative resources. As discussed previously in Table 4-25, only Florida and Georgia have ground water quality standards in place. Much less is known about the emergency and administrative capacities of southeastern states.

The general picture which emerges is that for most states in the Southeast, ground water management is not currently a prominent political issue. This largely reflects the historical abundance of surface and ground water, a legal system that has been predisposed to protect the autonomy of individual users, and the general absence of visible events or accidents to focus public attention on ground water. Thus, it appears that important needs are (1) to assess the perceptions of state officials about the importance of ground water problems and their preferences for responding to future threats, and (2) to inventory the status of existing ground water information systems, emergency response capabilities, and administrative capacity.

TABLE 4-26: ELEMENTS OF STATE GROUND WATER MANAGEMENT

I. Awareness of Ground Water Problems

- A. Is ground water protection viewed as a state priority?
- B. Has ground water been specifically defined in state environmental statues?
- C. What is the extent of public discussion or education about ground water issues?

II. Information Capacity

- A. Have ground water resources been adequately defined and characterized?
- B. Are procedures developed for monitoring ground water resources?
- C. Are there specific ground water research programs within the state?
- D. Does the state have a long-range planning capacity which includes concerns for ground water resources?

III. Status of Ground Water Standards

- A. Is there an explicit protection policy which identifies goals and objectives of ground water management?
- B. Have ground water standards been adopted?
- C. Are standards currently under consideration in the state?
- D. Are critical ground water areas designated?

IV. Emergency Capacity

- A. Do states have an inventory or site log of potential contamination sources?
- B. Do any programs exist for handling emergency waste spills other ground water pollution accidents?
- C. Have clean-up procedures been specified, including funding, notification, evacuation, and compensation?

V. Administrative Capacity

- A. Administrative Reponsibility
  1. Has a central agency been designated to administer ground water programs?
  2. Is there a planning component specified?
  3. Is there a program evaluation capacity?
  4. What is the commitment of financial and personnel resources for implementation and enforcement?
- B. Coordination and Integration of Programs
  1. Are there any mechanisms for coordinating federal, state, regional, and local agencies?
  2. Are there any mechansims for coordinating program responsibilities (RCRA, TSCA, SDWA, UIC, etc.)?
  3. Is there a capacity for conjunctive management of surface and ground water?
  4. Are administrative procedures flexible enough to account for regional differences and to allow for continuous modifications of programs?

4.6.4 Limited Local Government Initiatives

It is difficult to generalize about local responsibilities for ground water quality protection. In part this reflects the nature of "local government" units--which include municipalities, counties, special districts, and multicounty planning agencies. The relative importance of each of these units, and the amount and effectiveness of coordination among them, varies considerably across the southeastern states. In addition, the significance of all local government agencies considered together varies substantially state-to-state; for example, in Florida local government units can exert significant state-authorized management authority over ground water, while in most other states of the Southeast the extent of local authority largely depends on factors specific to the local area.

For the Southeast in general, local governments do not exert a great deal of authority over ground water quality, for many of the reasons already discussed--low saliency of ground water quality issues, and dependence on state and federal agencies for statutory direction and financial and technical resources.[1] In addition, it is at the local level where conflicts between development and environmental interests frequently are felt most strongly; it can be very difficult for local agencies to show that economically valuable development should be balanced with ground water protection values.

Local governments do have some responsibility for ground water quality in three principal areas--sewage facilities and services, zoning, and planning. Several local agencies may be involved in these three areas; in addition to city governments, these include:

- Special districts, such as the South Florida Water Management District, which has broad responsibilities for water resource management, including flood control, provision of water supplies, and approval of water-related components of land-use plans;
- County agencies, such as the Broward County (Florida) Environmental Quality Control Board, which is largely a regulatory agency responsible for monitoring surface

---

[1] There have been few federal initiatives designed to improve local government capacity to manage ground water. Although 208 programs did result in some local ground water programs, 208 was directed at surface water, and 208 programs no longer receive federal funds. The Farmers Home Administration provides grants and loans for water supply planning and sewer projects. These funds have contributed to the growth of rural water districts and indirectly encouraged population growth in rural areas.

and ground water quality and reviewing plans for wastewater treatment and disposal;

- Multicounty planning agencies, such as the Central Midlands Regional Planning Council (South Carolina), which plans and coordinates programs among several counties;
- Semipublic or private utilities, such as private sewer utilities which provide sewer service to residential subdivisions; and
- Local or regional offices of state agencies which, although technically state agencies, are typically staffed locally and responsive to local values and interests.

Among the sewer, zoning, and planning functions, provision of sewer facilities is the most universal among local governments across the study area. Perhaps the key issue associated with sewer services is coordination of services among the variety of agencies typically involved. For example, in the metropolitan area of Columbia, South Carolina, over 170 public, private, and semipublic sewage treatment systems are responsible for discharging directly into local rivers and streams. Such a disperse system makes monitoring of potential contamination virtually impossible, including attempts to understand cumulative effects. In fact, in 1978, metropolitan Columbia was ranked as the top water pollution problem area in South Carolina. Attempts to develop countywide central sewer services have been unsuccessful, largely because of the failure of initiatives to tie in with existing services or to increase property taxes to finance construction. This example highlights the difficulty local governments increasingly face as they try to finance new projects to protect environmental resources.

Planning and land use control responsibilities are closely related. Together, they represent a significant potential area of local authority to protect ground water, primarily through land use controls.[1] However, zoning represents a relatively comprehensive, and perhaps somewhat radical approach for many local governments; thus, several barriers exist to its use. First, it requires an awareness that problems currently exist or may exist in the future

---

[1] Zoning is based on the police power of states, which allows states to regulate or restrict individuals and businesses in the rights of both persons and property. Protection of public health, safety, convenience, nuisance, fraud, and morals are all based on police powers. While police powers originate with the state, they are frequently delegated to local governments, as is the case for zoning (see Chapter 8).

--this frequently necessitates planning and/or informational capacity. Even in southern Florida where ground water issues have long been recognized, "proving" that new developments will cause ground water problems is frequently difficult if not impossible. Secondly, even if problems are recognized, controlling land use through zoning is usually in direct conflict with developmental interests, which are frequently more economically and politically important than environmental values. Thirdly, zoning is nearly always a county and municipal responsibility, yet local planning capacity, if it exists, is frequently independent of local zoning agencies. For example, Lexington and Richland counties (surrounding Columbia, South Carolina) do not have their own planning staff--they depend on the regional planning council. Thus, although planning expertise may exist, it is frequently not directly linked to the institutions responsible for controlling land use.

An exception to these general patterns exists in counties of southern Florida, where water resource issues have been important items on the public agenda for years. The metropolitan Dade County Department of Environmental Resource Management has used zoning to protect a 250 squaremile area east of Everglades National Park and west of the urbanized area of the county. Because this is an important aquifer recharge area, residential development is limited to one unit per 40 acres. Further, considerable cooperation exists among local governments and agencies in this area. For example, the South Florida Water Management District, one of five local management agencies created by the State of Florida, and the U.S. Geological Survey are providing data on well characteristics for county agencies in Palm Beach, Broward, and Dade counties to develop a coordinated well field protection program. The objective is to implement ordinances in Palm Beach and Broward counties and upgrade one already enacted in Dade County to provide development guidance for land uses surrounding well fields based on travel times of pollutants.

4.7 SUMMARY AND CONCLUSIONS

Ground water is the source of drinking water for nearly 70 percent of the population of the Southeast, and for nearly the entire rural population. Ground water pollution in the Southeast as elsewhere, is characterized by highly localized incidents rather than regionwide contamination of aquifers; however, due to geological factors, some regions such as Florida and the coastal plains, have experienced more frequent problems. Indications suggest that this trend of deterioration will continue unless measures are taken to reduce the number of localized incidents of ground water pollution.

Apart from the occurrence of halogenated hydrocarbons in drinking water (a national problem in many countries), ground water pollution primarily results from localized activities. Examples are: acid drainage from coal mining in the Appalachian region of Kentucky; septic tanks along the North Carolina coast; leaks from deteriorating underground storage tanks in Florida; leaching from landfills in South Carolina; and fertilizers and pesticides in the fruit-producing areas of South Carolina. The potential for pollution can be either enhanced or reduced by geological features of the area, and once ground water is polluted it remains a local problem for some time after its occurrence due to the slow diffusion and degradation of pollutants.

4.7.1 Institutional and Management Issues

The authority for the design and implementation of regulatory actions to control sources of ground water pollution is dispersed among federal, state and local governments. At the federal level, the Federal Insecticide, Fungicide, and Rodenticide Act regulates the use of these hazardous materials in agriculture; the SDWA provides standards for drinking water and the RCRA and CERCLA go a long way toward regulating the disposal of hazardous waste. However, these Acts do not establish clear goals for ground water protection; for example, environmental and ecological criteria and standards were not included. EPA has proposed a preliminary "ground water protection strategy" which includes guidelines for ground water standards, classification of aquifers, encouragement of the development of state ground water protection strategies, and coordination between federal and state agencies. However, this policy document has not been adopted, and it is uncertain what strategy, if any, will be implemented. Current trends in decentralization of government authority and reduced emphasis on federal regulation suggest that state and local governments are going to need to increase their capability in ground water protection.

Most states have followed federal initiatives and have begun to implement programs dealing with hazardous waste management, deep well waste injection regulations, and to a lesser extent, oil and gas brine disposal and prevention of salt water intrusion. Some states have also adopted an active role in facilitating the siting of hazardous waste management facilities. At the state level, North Carolina and Florida have adopted a systematic approach which includes regulation of pollution sources, ground water quality standards, and an aquifer classification system. South Carolina and Georgia have developed a range of quality standards and contamination controls. Overall, for most states of the Southeast, ground water quality has not been a prominent issue to act as a driving force in the formulation and implementation of systematic, comprehensive ground water quality protection legislation.

At the local level the responsibility over zoning, provision of drinking water and sewage facilities, and provision of other services give much authority to local governments which could be used to impose regulations for the protection of ground water quality.

This position of authority is, however, undermined by strong political pressures whenever conflicts arise between economic development, private property rights, and environmental interests. For the most part, local governments have not taken a strong role in ground water quality protection.

The diversity of the sources of ground water pollution and the multiplicity of administrative and statutory authorities which may deal with them does not allow for blanket measures to be taken at any particular level of government. Rather, they call for sets of complimentary measures to be designed and implemented in close cooperation among federal, state, and local governments. Policy options for improving institutional arrangements in protecting ground water quality are discussed in chapters 6, 8, and 9.

4.7.2 Hazardous Waste Disposal

Hazardous wastes are an important source of ground water pollution which has affected, to varying degrees, all eight states of the Southeast. Centers of chemicals manufacturing in North Carolina, Tennessee, Kentucky, and the Gulf Coast of Alabama generate large volumes of hazardous waste much of which is treated and disposed on site. Some of these on-site facilities may not meet EPA interim final standards and have the option to comply or discontinue their operations as of February 1983. This may increase the already large number of inactive and abandoned hazardous waste management facilities which are the most dangerous sources of ground water pollution. Other on-site landfills and lagoons may leak hazardous waste into aquifers before their applications for a final operating permit are reviewed and either approved or denied by EPA. Another source of concern is the large number of small generators of hazardous waste (less than 1,000 kg per month), which are not obligated by RCRA to comply with the manifest system. Some of these generators may dispose of their wastes illegally in municipal landfills and sewers, or by dumping it along roadsides rather than paying the sometimes high costs of disposal in approved facilities. Finally, the shortage of off-site commercial hazardous waste management facilities, and the virtual standstill in establishing new capacity because of public opposition, perpetuates the operation of older, on-site facilities which pose the most severe risks to ground water quality. Given this situation, the overwhelming issue for ground water disposal is whether governments at all levels are prepared to enforce the RCRA and CERCLA statutes quickly and thoroughly. If there are long periods before the regulations are enforced, ground water quality will suffer.

As new hazardous waste management facilities are regulated by RCRA, and established operating facilities will eventually be regulated, the most serious danger for ground water degradation becomes leaking of old abandoned hazardous waste disposal sites. Clean-up operations in the framework of CERCLA were slow to start and will not in all probability be completed within the current five-year authorization period for CERCLA (1980-85). The large number of such sites, the hazardous nature of the waste, the technical and financial constraints, and the shortage of new sites in which this waste has to be relocated, make clean-up a much larger operation than originally anticipated and a longer period of time will be needed to accomplish the goals.

In the Southeast there are only two commercial hazardous waste land disposal facilities (South Carolina and Alabama), and five of the eight states are overall exporters of hazardous waste. The shortage of sites creates a bottleneck in the flow of hazardous waste from generators to disposal and raises the cost of transport and disposal, thus encouraging the continued operation of hazardous waste management facilities which may not meet RCRA standards. It may also act as a constraint to the industrial development of some areas of the Southeast. Local public opposition to the siting of hazardous waste management facilities is the most important cause for this shortage. This opposition is based on the fear of risks from hazardous waste management facility in close proximity to a community while the employment and income benefits appear small. Local authorities have at least two instruments which can be used to improve the cost/benefit balance of these impacts: zoning and local taxes. Policy options to deal with some of these issues are identified and discussed in Chapter 6.

4.7.3 Septic Tanks

Septic tanks are one of the most frequent causes of ground water contamination. They are a continuing concern because their use is likely to expand due to growth in nonurban areas which have no or limited access to central sewer systems. The main concern is that microbial and chemical pollution of ground water may occur either by saturating the soil due to high density of septic tanks or by allowing their use in areas where soils are inappropriate. Another concern is the use of organic solvents and degreasers for cleaning septic tanks. Their use leads to ground water pollution by increasing the load of organic material in the soil and because most organic solvents used (e.g., TCE's) have been found to cause cancer in animals. Policy options for dealing with these concerns, such as improved septic tank technologies, improved regulations on their use, and controls on septic tank cleaners, are discussed in Section 6.2.

4.7.4 Other Nonpoint Sources and Land-Use Issues

In addition to septic tanks, ground water pollution results from a variety of other nonpoint sources. Ground water pollution incidents from underground storage tanks have been frequent, particularly in areas where the water table is shallow such as Florida and the South Atlantic Coast. Chemicals, and especially gasoline and other refinery products have leaked directly into aquifers.

Runoff from urban areas and from areas of intensive agriculture are also a problem for ground water--although probably less so than surface water. Urban runoff can contain suspended solids, toxic substances (including heavy metals and pesticides), microorganisms, oxygen-demanding materials, nutrients, and oil and grease. Given the projected population growth of the Southeast and the difficulty of controlling this source, urban runoff is likely to become a greater problem in the future. Three agricultural practices have caused ground water contamination: use of fertilizers, use of pesticides, and animal feed-lots. Fruit and vegetable farming, for example, in Florida and the Carolinas has been the cause of nitrate and pesticide contamination of ground water. In many cases, ground water pollution results from bad farming practices, such as excessive use of fertilizers and pesticides. Best Management Practices (BMPs) have been developed, and are being reviewed and updated to reduce surface and ground water pollution. These are discussed briefly in Section 6.3.

Coal production is the major mining operation in the Southeast (Kentucky, Tennessee, Alabama) and acid drainage has in the past affected both surface and ground water. The Surface Mine Control and Reclamation Act has regulated coal mining operations so that ground water pollution from this source should be reduced if the regulations are enforced. However, even if they are enforced, there remains considerable technical uncertainty as to just how well the mitigation measures will work over the long term. Phosphate mining on the coastal plain disrupts aquifers (particularly in Florida), and the leaching of mining waste pollutes both surface and ground water. The diversity of minerals and mines, and the localized nature of ground water contamination require a diversity of practices to protect such contamination from occurring. With respect to oil and gas drilling, regulations to protect ground water are not always adequately enforced. In most states, the regulatory agencies are not environmental agencies, but rather agencies more concerned with promoting oil and gas development. Abandoned, unplugged boreholes are another cause of ground water pollution. Improvements in regulating programs are needed to deal with these malpractices. Some policy options to address these concerns are discussed in Section 6.4.

The potential of the above nonpoint sources to pollute ground water is intimately related to land use practices. Although controls can be implemented for each source, ground water quality protection cannot be assured if these activities are located in critical aquifer recharge areas. This fact was recognized in the "sole-source aquifer" provisions of the SDWA but regulatory action possible under this Act is very limited in scope. In only a few instances currently in the Southeast, do state and local governments explicitly use ground water protection criteria in formulating land use plans or controls.

4.7.5 Monitoring for Ground Water Pollution

Given the complexity of ground water systems, the diversity of the sources of pollution, the technical and scientific imponderables, the shortage of funds, and the multiplicity of institutions, attempts to coordinate monitoring activities over a large area like the Southeast will be a long and arduous task. Likewise, attempts to develop comprehensive ground water data bases would be of questionable cost effectiveness. Currently, problems include lack of coordination and data exchange among agencies, inadequate technical support for monitoring, inconsistent terminology for aquifers, and inadequate unitization of existing data.

Monitoring ground water quality is essential for management and policymaking. Much of its usefulness is for managing local problems; hence local and state regulatory agencies are in an effective position to evaluate the usefulness and adequacy of monitoring programs. Federal institutions such as the USGS and EPA may be best suited for longer term scientific studies, e.g., developing predictive models of aquifer behavior.

4.7.6 Drinking Water

Provision of high quality drinking water and ground water quality protection are closely related: ground water supplies 67 percent of the drinking water in the Southeast and in rural areas it supplies 98 percent of the drinking water with little or no treatment. On a national basis, 43 percent of community systems were found recently to be in violation of SDWA regulations, including violations of standards, lack of public notification, and insufficiently trained manpower. Another national study of rural households (mostly private wells) revealed that 63 percent were contaminated and possibly unsafe, with the most widespread problem being bacterial contamination. Results from those studies specific to the Southeast were not available. Based on a telephone survey of state officials in the Southeast, it was reported that compliance with SDWA regulations for both community and noncommunity systems ranged from a low of 75 percent in Flordia to 100 percent in Alabama (although officials in some states could not provide estimates); these findings seem to contrast with the national studies.

Three problems and issues were identified. One concerns the adequacy of drinking water standards. Although over 700 chemicals have been identified in drinking water supplies, only 16 maximum contaminant levels have been established under the SDWA. Of particular concern are toxic organic chemicals which have recently been detected at low levels in large numbers of wells (and surface waters) in the Southeast and nationally. For example, measurements of nine volatile organic chemicals in water supply wells in six southeastern states detected trace levels ranging from as few as 5 percent of the wells in Kentucky to as many as 50 percent of the wells in Florida. A major difficulty is the uncertain link between trace levels of these chemicals in drinking water and increased cancer rates or other health effects.

A second issue concerns the gaps and overlaps in existing regulatory programs to protect drinking water quality. Problems with the SDWA include the fact that it does not apply to small water supply systems, the sole-source aquifer provisions of the Act are limited in scope, and there have been deficiencies in implementation. A number of other federal and state laws also address various aspects of drinking water protection (e.g., CWA, RCRA, and CERCLA), but combined they lead to overlaps and also leave several gaps. For example, CERCLA (Superfund) addresses the most critical cases of hazardous waste disposal sites, but thousands of smaller cases are not included. Also, no federal laws and a few state laws establish ground water quality standards. Finally, land use controls to protect drinking water supplies, which are potentially one of the most effective mechanisms, are seldom used in the Southeast.

A third drinking water problem relates to the high cost of monitoring and treating drinking water to remove synthetic organic chemicals. Costs for treatment will depend on the technology chosen and there are a large number of alternatives with differing effectiveness depending on the specific set of pollutants to be removed. Costs are also quite sensitive to the scale of application. Although treatment costs for synthetic organic chemicals do not seem prohibitive, especially for systems serving over 10,000 people, it will be difficult to force communities to employ such treatment methods because of the uncertain benefits to health and the problems in financing such public works projects.

REFERENCES

American Petroleum Institute (API). 1978 and updates. Basic Petroleum Data Book: Petroleum Industry Statistics. Washington, DC: American Petroleum Institute.

Bartlett, Richard E. 1979. "State Ground Water Protection Programs: A National Summary." Ground Water 17: 89-93.

Bennett, G. D. 1979. "Regional Groundwater Systems Analysis." Water Spectrum 11 (4): 36-42.

Booz, Allen & Hamilton, Inc., and Putnam, Hayes & Bartlett, Inc. 1980. Hazardous Waste Generation and Commercial Hazardous Waste Management Capacity. Washington, DC: Environmental Protection Agency.

Burge, W. D., and P. B. Marsh. 1978. "Infectious Disease Hazards of Landspreading Sewage Wastes." Journal of Environmental Quality 7 (January/March): 1-9.

Burmaster, D. E., and R. H. Harris. 1982. "Groundwater Contamination: An Emerging Threat." Technology Review 85 (July): 50-62.

California. Toxic Waste Assessment Group. 1981. Alternatives to the Land Disposal of Hazardous Wastes: An Assessment for California. Sacramento, CA: Governor's Office of Appropriate Technology.

Canter, L. W., R. C. Knox, and R. P. Kamat. 1982. "Evaluation of Septic Tank System Effects on Ground Water Quality" (draft). National Center for Ground Water Research, Norman, OK, May.

Chisholm, James L. 1981. "New Programs in Surface Mine Hydrology." In Groundwater Management: Proceedings of a Southeast Regional Conference, edited by James C. Warman, 139-51. Auburn, AL: Auburn University, Water Resources Research Institute.

Colston, N. W., Jr. 1974. Characteristics and Treatment of Urban Land Runoff. Cincinnati: U.S. Environmental Protection Agency, National Environmental Research Center.

Copenhaver, Emily D., Richard J. Olson, and Patricia L. Rice. 1978. Regional Environment-Energy Data Book: Southern Region. Oak Ridge, TN: Oak Ridge National Laboratory.

Council on Environmental Quality. 1979. Environmental Quality 1978: Ninth Annual Report. Washington, DC: Government Printing Office.

______. 1980. Environmental Quality 1979: Tenth Annual Report. Washington, DC: Government Printing Office.

______. 1981. Contamination of Ground Water by Toxic Organic Chemicals. Washington, DC: Government Printing Office.

______. 1981. Environmental Quality 1980: Eleventh Annual Report. Washington, DC: Government Printing Office.

Craun, G. F. 1979. "Waterborne Disease: A Status Report Emphasizing Outbreaks in Groundwater Systems." Ground Water 17: 183-91.

Dade County (Florida) Department of Environmental Resources Management. 1980. "Protection of Potable Water Supply Wells Program." N.p.

Dawson, James. 1979. "State Ground Water Programs--Inadequate." Ground Water 17: 102-8.

Day and Zimmerman, Inc. 1982. Miami-Dade Water and Sewer Authority Water Division Report. Philadelphia: Day and Zimmerman, June.

Deland, Michael R. 1981. "Superfund: Its Unfulfilled Potential." Chemical and Engineering News 15 (December): 1417.

Dinger, James. 1983. Kentucky Geological Survey. Personal communication.

Drewry, W. A., and R. Elizassen. 1968. "Virus Movement in Groundwater." Journal of the Water Pollution Control Federation 40 (August): R257-71.

Ecolibrium. 1982. "Is Nothing Sacred?" 11 (Fall).

Environmental Dynamics, Inc. 1979. A Regional Facility for the Treatment and Disposal of Hazardous Wastes Generated within the Appalachian Region of South Carolina. Springfield, VA: National Technical Information Service.

Environmental Law Institute. *Legal and Institutional Approaches to Water Quality Management Planning and Implementation*. Washington, DC: Environmental Protection Agency.

Everett, L. G. 1976. *Monitoring Ground Water Quality: Methods and Costs*. General Electric TEMPO Report. Springfield, VA: National Technical Information Service.

______. 1980. *Ground Water Monitoring*. Schenectady, NY: General Electric Co., Technology Marketing Operations.

Fairchild, D. M., and L. W. Canter. 1982. *Evaluation of Impacts of Oil and Gas Field Activities on Ground Water Resources*. Report No. 82-1. Norman, OK: National Center for Ground Water Research.

Federal Register. 1982a. "Hazardous Waste Management System: General, Standards for Generation of Hazardous Waste, State Hazardous Waste Program Requirements." 47 (March 4): 9336-44.

______. 1982b. "National Revised Primary Drinking Water Regulations, Volatile Synthetic Organic Chemicals in Drinking Water." 47 (March 4): 9350-58.

______. 1982c. "National Primary Drinking Water Standards, Trihalomethanes." 47 (March 5): 9796-79

Florida Department of Environmental Regulation. 1982. *Economic Impact Statement (EIS) for Proposed Revisions to Chapters 17-3, 17-4, F.A.C. Ground Water Standards*. Tallahassee, FL: The Department, July.

Florida Department of Environmental Resources Management. 1981. *Ground Water Quality Monitoring Program, Dade County, Fla*. N.p.

Franks, Bernard J. 1981. *Land Application of Domestic Wastewater in Florida: Statewide Assessment of Impact on Ground Water Quality*. Geological Survey Water Resources Investigation 81-3. Washington, DC: Government Printing Office.

Gass, T. E., J. H. Lehr, and H. W. Heiss, Jr. 1977. *Impact of Abandoned Wells on Ground Water*. Worthington, OH: National Water Well Association.

Gerba, C. P. N.d. "Virus Occurrence in Ground Water." In *Proceedings: Microbial Health Consideration of Soil Disposal of Domestic Wastewaters*. Conference sponsored by EPA, May 11-12, 1981. Springfield, VA: National Technical Information Service. Forthcoming.

Giese, R. G. 1982. "A State Ground Water Management Program." *Ground Water Monitoring Review* 2 (Winter): 26-30.

Ground Water Monitoring Review. 1983. "How Serious is Ground Water Contamination and What is EPA Doing About It?" 3 (Winter): 20.

Hagedorn, C., E. L. McCoy, and T. M. Rahe. 1981. "The Potential for Ground Water Contamination from Septic Effluents." Journal of Environmental Quality 10 (1): 1-8.

Hampton, N. F. 1976. Monitoring Groundwater Quality: Data Management. General Electric TEMPO report. Springfield, VA: National Technical Information Service.

Hall, Timothy, Steven Ballard, and I. L. White. 1978. "Western States and National Energy Policy: The New States' Rights." American Behavioral Scientist 22 (2): 191-212.

Horne, Amy. 1982. "Groundwater Policy, A Patchwork of Protection." Environment 24 (April): 6-11.

Howells, David H. 1981. "Comments on a National Ground Water Protection Strategy." Ground Water 19: 466-68.

Johnson, Wilton, and J. Paone. 1980. Land Utilization and Reclamation in the Mining Industry, 1930-80. Pittsburgh, PA: U.S. Bureau of Mines.

Kentucky Department for Natural Resources and Environmental Protection. Division of Water Quality. 1980. Kentucky 305(b) Report to Congress on Water Quality, Vol. 1. Frankfort, KY: Dept. for Natural Resources and Environmental Protection.

Larsen, E. 1980. "TCE, Solvent Suspected as Cancer Cause, Frequently Shows up in Drinking Water." Wall Street Journal (August 12): 44.

Lazar, E. C., R. Testani, and A. B. Giles. 1976. "The Potential for National Health and Environmental Damages from Industrial Residue Disposal." In National Conference on Disposal of Residues on Land, 196-202. Washington, DC: Environmental Protection Agency.

Leinesch, W. C. 1977. Legal and Institutional Approaches to Water Quality Management Planning and Implementation. Washington, DC: Environmental Protection Agency.

Love, O. T., Jr., and R. G. Eilers. 1982. "Treatment of Drinking Water Containing Trichloroethylene and Related Industrial Solvents." American Water Works Association Journal 74 (August): 413-25.

McCaslin, John C. 1981. "Drilling Climbs in Southwestern Alabama's Part of the Mississippi Salt Basin." Oil and Gas Journal 79 (November 9): 355-56.

______. 1983. "Survey Points to 69,120 Wells This Year." Oil and Gas Journal 81 (January 31): 104.

Mason, John. 1983. Staff headquarters, U.S. Environmental Protection Agency, Region 4. Personal communication.

Miller, D., P. Hackenberry, and F. DeLuca. 1977. Groundwater Problems in the Southeastern United States. Washington, DC: Environmental Protection Agency.

Mississippi. 1982. An Act to Amend Section 17-17-27, Mississippi Code of 1972: Report of the Conference Committee, H.B. No. 781.

Mlay, M. 1982. EPA Office of Drinking Water. Personal communication, November.

Moore, Gardner & Associate. 1979. On-Site Waste Water Treatment and Disposal Alternatives. Georgetown, SC: Waccamaw Regional Planning and Development Council.

National Center for Ground Water Research. 1980a. Effects of Oil and Gas Field Activities on Ground Water Quality. Norman, OK: National Center for Ground Water Research.

______. 1980b. Effects of Coal Extraction and Development on Ground Water Quality. Norman, OK: National Center for Ground Water Research.

National Research Council. 1979. Surface Mining of Non-Coal Minerals. Washington, DC: National Academy of Sciences.

______. 1981. Coal Mining and Ground Water Resources in the United States. Washington, DC: National Academy Press.

Noonan, M. J., and J. F. McNabb. 1979. "Contamination of Canterbury Ground Water by Viruses." In The Quality and Movement of Ground Water in Alluvial Aquifers of New Zealand. Canterbury, New Zealand: Lincoln College, Department of Agricultural Microbiology.

North Carolina Department of Human Resources. 1978. Hazardous or Difficult to Handle Waste Survey Report. Springfield, VA: National Technical Information Service.

North Carolina Department of Natural Resources and Community Development. 1982. Personal communication, June.

Oil and Gas Journal. 1982. "Total Wells Drilled in the United States (API)." (June 7): 217.

Peek, Harry. 1981. "Ground Water Program, Problems, and Needs in North Carolina." In Groundwater Management: Proceedings of a Southeast Regional Conference, edited by James C. Warman, 42-58. Auburn, AL: Auburn University, Water Resources Research Institute.

Pendygraft, G. W., F. E. Schlegel, and M. J. Huston. 1979a. "Organics in Drinking Water: A Health Perspective." American Water Works Association Journal 71 (March): 118-26.

______. 1979b. "Organics in Drinking Water: Maximum Contaminant Levels as an Alternative to the GAC Treatment Requirement." American Water Works Association Journal 71 (April): 174-83.

Roberts, Rebecca S., and Lisa Mathis Butler. 1983. "Land Use and Groundwater Policy Formation." Paper presented at the 61st Annual Meeting, Southwestern Social Science Association, Houston, TX, March 23-26.

Scalf, M. R., W. J. Dunlap, and J. F. Kreissl. 1977. Environmental Effects of Septic Tank Systems. Ada, OK: U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory.

Schaub, S. A., and C. A. Sorber. 1977. "Virus and Bacteria Removal from Wastewater by Rapid Infiltration through Soil." Applied and Environmental Microbiology 33: 609-19.

Science and Public Policy Program (S&PP). 1981. Energy From the West: Technology Assessment of Western Energy Development. Norman: University of Oklahoma Press.

______. 1983. Southern Regional Environmental Assessment: Environmental Status Report. Washington, DC: Environmental Protection Agency, Office of Research and Development.

Singer, G. L. 1982. "The Need for Preventive Control of Drinking Water Contaminants." American Water Works Association Journal 74 (October): 18, 49.

South Florida Water Management District. 1980. Water Quality Monitoring Network. Technical memorandum, annual report.

Straub, C. P. 1973. "Public Health Implications of Land Disposal of Wastewater Effluents and Sludges." In Conference Proceedings, Land Application of Municipal Waste Waters. St. Paul: University of Minnesota.

Sun, Marjorie. 1982. "EPA Issues Hazardous Waste Rules." *Science* 217 (July 30):

Tripp, J. T. B., and A. B. Jaffe. 1979. "Preventing Groundwater Pollution: Towards a Coordinated Strategy to Protect Critical Recharge Zones." *Harvard Environmental Law Review* 3 (1): 1-47.

U.S. Bureau of the Census. 1970. *Housing Characteristics, 1970*. Washington, DC: Government Printing Office.

U.S. Congress. Office of Technology Assessment. 1979. *The Direct Use of Coal: Prospects and Problems of Production and Combustion*. Washington, DC: Government Printing Office.

U.S. Department of Commerce. Bureau of Economic Analysis. 1980. *Regional Economic Projections*. Washington, DC: Bureau of Economic Analysis.

U.S. Department of Energy. Energy Information Administration. 1981. *Energy Data Report: Weekly Coal Production*. Weekly Coal Report no. 198, July 17.

U.S. Environmental Protection Agency (EPA). 1980a. *Design Manual: On-site Wastewater Treatment and Disposal Systems*. Washington, DC: Environmental Protection Agency.

______. 1980b. *Planning Workshops to Develop Recommendations for a Ground Water Protection Strategy: Appendices*. Washington, DC: Environmental Protection Agency, June.

______. Office of Air and Water Programs. 1973. *Methods for Identifying and Evaluating the Nature and Extent of Nonpoint Sources of Pollutants*. Washington, DC: Environmental Protection Agency.

______. Office of Drinking Water. 1979. *National Secondary Drinking Water Regulations*. Washington, DC: Environmental Protection Agency.

______. Office of Drinking Water. 1980. *Proposed Ground Water Protection Strategy*. Washington, DC: Environmental Protection Agency.

______. Office of Research and Development. 1980. *Environmental Outlook 1980*. Washington, DC: Government Printing Office.

______. Office of Water and Waste Management. 1979. *Siting of Hazardous Waste Management Facilities and Public Opposition*. Washington, DC: Environmental Protection Agency.

______. Office of Water Supply and Office of Solid Waste Management Programs. 1977. The Report to Congress: Waste Disposal Practices and Their Effects on Ground Water. Washington, DC: Environmental Protection Agency.

U.S. General Accounting Office. 1982. States' Compliance Lacking in Meeting Safe Drinking Water Regulations. Washington, DC: Government Printing Office.

U.S. Water Resources Council. 1981. State of the States: Water Resource Planning and Management; Ground Water Supplement. Washington, DC: Water Resources Council.

Warman, James C., ed. 1981. Ground Water Management: Proceedings of a Southeast Regional Conference. Auburn, AL: Auburn University, Water Resources Research Institute.

Water Well Journal. 1982. "Safe Drinking Water Act Increases Paperwork--Not Standards." 36 (December): 16.

Weimar, Robert A. 1980. "Prevent Groundwater Contamination." Water & Wastes Engineering (February).

Wellings, F. M., et al. 1975. "Virus in Groundwater." In Proceedings: Second National Conference on Individual On-site Wastewater Systems. Ann Arbor, MI: National Sanitation Foundation.

Weston, Roy F., Inc. 1978. Residual Waste Management Plan. Montgomery: Alabama Water Improvement Commission.

Wickersham, Ginia. 1981. "A Preliminary Survey of State Ground Water Laws." Ground Water 19: 321-27.

Wilmington-New Hanover Planning Department. 1980. Classification of Soils in New Hanover County for Septic Tank Suitability. Technical Report No. 9. Wilmington, NC: Wilmington-New Hanover Comprehensive Planning Program.

Yang, Edward. 1981. Assessment of Problems Related to Siting Hazardous Waste Management Facilities: A Case Study of EPA Regions 4 and 6 (draft). Washington DC: Environmental Law Institute.

APPENDIX A

Individuals contacted for Hazardous Waste Information

EPA Region 4

Mr. Donald R. Hunter
Waste Engineering Section
U.S., EPA

Alabama

Mr. Alfred J. Chipley, Director
Division of Solid and
Hazardous Waste Management

Florida

Mr. Robert W. McVety,
Environmental Administrator
Solid Waste Section
Department of Environmental
Regulation

Georgia

Mr. Mike Arnett
Land Protection Branch
Environmental Protection
Division
Department of Natural Resources

Kentucky

Mr. J. Alex Barber
Division of Waste Management
Department of Natural Resources
and Environmental Protection

Mississippi

Mr. Jack M. McMillan, Director
and
Mr. David Lee
Division of Hazardous Waste
Management
Department of Natural Resources

North Carolina

Mr. O. W. Strickland, Head
Solid and Hazardous Waste
Management Branch
Environmental Health Section
Department of Human Resources
Division of Health Service

South Carolina

Mr. Robert E. Malpass, Chief
Bureau of Solid and Hazardous
Waste Management
Department of Health and
Environmental Control

Tennessee

Ms. Phyllis Garman
Division of Solid Waste
Management
Department of Public Health

Hazardous Waste Management Industry

Mr. Roger Henson
Chemical Waste Management Co.
Enelle, Alabama

Mr. Larry Johnson
SCA Services
Pinewood, South Carolina

Mr. Herschel Roberts
U.S. Pollution Control, Inc.
Oklahoma City, Oklahoma

APPENDIX B

SUMMARY OF TELEPHONE SURVEY ON GROUND WATER MONITORING

TABLE B-1: NUMBER OF CONTACTS MADE DURING TELEPHONE SURVEY

State	State Ground Water Agency	USGS	State Geological Survey	Underground Injection Control	Total
Al	3	2	1	2	8
FL	4	1	1	1	7
GA	2	1	1	1	5
KY	2	1	1	1	5
MS	4	2	1	2	9
NC	3	1	1	1	6
SC	5	1	1	1	8
TN	4	1	2	1	8
Total	27	10	9	10	56

TABLE B-2: TELEPHONE SURVEY QUESTIONS

Agency Responsibility

1. What agencies are responsible for ground water monitoring?
2. Are they the same as the agency responsible for ground water quality and monitoring for drinking water standards? What is the overlap?
3. Where do ground water monitoring programs fit in relation to other state water programs?
4. What agencies are responsible for ground water availability tracking?
5. What is the status of ground water use (and projections) and pumpage reports?
6. What state regulations exist for ground water monitoring of quality and quantity?

Ground Water Monitoring

1. How many wells in state supply ground water for drinking water? For other uses?
2. What percent of drinking water supply wells are monitored for quality and availability? How frequent are analyses made? What parameters are measured? What criteria are used to determine compliance (e.g., primary and secondary drinking water standards)? How is the information reported?
3. Can you give specific examples: on noncompliance of ground water supplies with SDWA requirements; noncompliance according to state regulations; and monitoring deficient areas where compliance/noncompliance cannot be determined?
4. How many other ground water supply wells are monitored around pollutant sources (mines, solid waste, industrial sites, landfills, other)? What parameters at disposal facilities are measured? What is the frequency of monitoring? Describe status of UIC program.
5. How many complaints are there related to quality/availability each year? Breakdown of types of complaints?
6. What areas are currently being studied because of ground water problems? Breakdown of numbers in classes I-V? What type of wells do you have (or expect) biggest problems from ground water contamination?

TABLE B-2 (continued)

Data Management

1. Describe federal, state, and local data management systems used by your agency:
    Use of computers;
    Where is the data stored;
    Inter-and intra-agency information flow and
    Who uses the information?

2. How can other state/federal agencies obtain information from your agency?

3. Does the public obtain information through public education programs?

4. Can the public obtain specific information on results of monitoring on pollution studies? If yes, what type, who is doing the work, and are there any problems?

5. Are models being used? Are models supplying information that aids management? Why?

Problem Definition

1. What is level of federal/state funding of your agency for current year; for ground water monitoring; for data managment?

2. How may people are involved with ground water monitoring or data management tasks?

3. Are there adequate numbers of trained staff?

4. Do you have any technical problems (e.g., laboratory procedures and sampling, incompatability of hardware/software) within agencies or between agencies?

5. Are there any political/institutional/social pressures (events) that influence ground water management policy decisons?

6. What are your agencies' problems in accomplishing its goals, particularly in relation to ground water monitoring and data management?

7. What do you see as solutions to these problems? What is their feasibility and advantages and disadvantages?

CHAPTER 5

GROUND WATER AVAILABILITY PROBLEMS AND ISSUES

5.1 INTRODUCTION

Historically, the availability of sufficient water resources to meet the demands of domestic, industrial, and agricultural users has not been a problem in the Southeast. In this area of the country lakes, rivers, and streams are abundant; ground water resources are widespread; and rainfall to replenish surface and ground water resources is plentiful. In general, this is not a region where water availability should be a problem if resources are managed properly. For the most part, water availability problems have resulted from drought conditions and have been confined to fairly localized areas.

However, some areas of the Southeast--much of Florida, the Atlantic coast, and localized inland areas--are experiencing water availability problems. Although these occurrences are localized in nature, they are becoming more common throughout many areas of the Southeast. Over the next two or three decades, increasing demands from irrigated agriculture, new or expanding industries, and population growth, as well as localized water quality problems limiting the total water available for consumptive use, could stress existing supplies. Ground water overdraft can adversely affect local economies and restrict both industrial and population growth. Avoiding or reducing these potential impacts will be made more difficult by weaknesses in the current legal and institutional system for managing ground water, lack of intergovermental cooperation, and political conflicts over issues such as land use control.

This chapter discusses several aspects of ground water availability. The following section (5.2) provides an overview of ground water use patterns and a discussion of specific problems created by ground water overdraft. Section 5.3 discusses political, legal, and institutional issues which can affect ground water management.

5.2 GROUND WATER USE AND PROBLEMS

Summary: Ground water is one of the Southeast's most important resources. The use of fresh ground water increased by 160 percent between 1960 and 1980. In 1980, ground water accounted for 41 percent of fresh water supplies in the Southeast (excluding thermoelectric power generation). Overall, Florida, Mississippi, and Georgia are the most dependent on ground water. Rural users in North Carolina, Florida, and Georgia are almost totally dependent on ground water as a source of supply. One of the most important uses of ground water is for drinking water. In 1970, almost 70 percent of the population in the Southeast obtained their drinking water from ground water sources; virtually all of the drinking water in rural areas came from ground water. As population and industrial growth continue in the Southeast, the adequacy of water supplies to meet future demands will become an increasingly important concern. Ground water overdraft to meet supply demands could increase the incidence of water quality degradation, subsidence, and the problems associated with lowered water tables.

5.2.1 Ground Water Use Patterns[1]

As indicated in Table 5-1, the use of fresh ground water in the Southeast increased by 160 percent between 1960 and 1980--from 3.2 to 8.4 billion gallons per day (bgd) of withdrawal. Florida uses the greatest amount of ground water and has experienced the largest absolute increase in use during this time period; withdrawals increased by 141 percent from 1.5 to 3.7 bgd. Most of this increase was due to increases in the amount of ground water used for agricultural purposes. Georgia, Mississippi, and North Carolina also have had large absolute increases in the use of fresh ground water during the past 20 years.

Tennessee is the only state in the Southeast to experience a decrease in the use of ground water between 1960 and 1980--from 609 to 446 million gallon per day (mgd). This is the result of a large reduction in the use of ground water as a source of supply for self-supplied industrial use between 1960 and 1970. Over the past 10 years, the use of ground water in Tennessee, as in the other states, has actually increased.

Overall, in 1980 the states in the Southeast relied on ground water for 41 percent of their fresh water supplies other than water

---

[1] The term "water use" in this section means withdrawal use--the amount of water withdrawn from its source. This is equivalent to "intake" or "water requirement" as used in industry and agriculture, respectively.

TABLE 5-1: GROUND WATER USE 1960-1980[a]
(millions of gallons per day)

State	1960	1970	1975	1980	Percent Change 1960-1980
Alabama	215	274	361	350	63
Florida	1,550	2,950	3,210	3,730	141
Georgia	424	627	793	1,160	174
Kentucky	108	163	151	233	116
Mississipi	617	730	1,093	1,487	141
North Carolina	174	430	550	769	342
South Carolina	141	167	195	229	62
Tennessee	609	294	370	446	-27
Southeast	3,229	5,635	6,723	8,404	160

Sources: Mackichan, K. A., and J. C. Kammerer 1961; Murray, C. R., and E. B. Reeves 1972; Murray, C. R. and E. B. Reeves 1977; and Solley, Chase, and Mann 1983.

[a] Includes water withdrawn for use for: (1) public supply (domestic, commerce, and industry); (2) rural (domestic and livestock); (3) irrigation; and (4) self-supplied industrial. The table does not include uses by electric utilities or saline water.

withdrawn for hydroelectric or thermoelectric power generation.[1] Between 1975 and 1980 (Table 5-2 and 5-3), ground water use in the Southeast increased approximately 25 percent, from 6.7 to 8.4 bgd. However, an even greater increase in the use of surface water resulted in an overall decline in the proportion of fresh water supplies withdrawn from ground water sources.

Of the states in the Southeast, Mississippi continues to be the most dependent on ground water.[2] In 1980, approximately 1.5 bgd were withdrawn, representing 77 percent of the state's fresh water supplies. Although Florida ranked second in dependence on ground water in 1980 (68 percent), it by far uses the greatest amount of ground water--3.7 bgd in 1980, which accounts for 44 percent of the ground water used in the Southeast. In 1980, Georgia relied on ground water for about half (51 percent) of its fresh water supplies; this was an increase of 8 percent and 367 mgd of withdrawal over 1975. In no other state did ground water account for more than 30 percent of the fresh water withdrawals in 1980.

Although ground water withdrawals increased in every state except Alabama between 1975 and 1980, the proportion of fresh water supplies accounted for by ground water decreased in two states (Alabama and North Carolina) and remained the same in two others (South Carolina and Tennessee). Thus, while the withdrawal trends indicate the continued increase in ground water use in the Southeast, in some areas larger withdrawals do not necessarily mean

---

[1] In the Southeast, only about 108 mgd of fresh ground water were withdrawn for use by utilities in 1980. In Florida and Kentucky this use accounts for 10 percent of the total fresh ground water used; but, in no other state does it account for more than 4.5 percent of the fresh ground water used. Saline ground water also has been excluded from all tables. Only Florida (42 mgd) and Alabama (1.4 mgd) use saline ground water for "other industrial uses" (nonelectric utility uses). Saline water is defined as water with more than 1,000 milligrams per liter (mg/l) of dissolved solids irrespective of the nature of the minerals present.

[2] The reader should keep in mind that presentation of ground water use data by state can mask regional differences within the state. For example, the use of ground water is much greater in the coastal plains region of North Carolina, South Carolina, and Georgia than in the Piedmont region of those states. In addition, state-wide data can mask site-specific differences. In the Columbia, South Carolina area, less than 25 percent of the population of Richland County is dependent on ground water for drinking water. However, in neighboring Lexington County, approximately 50 percent of the population relies on ground water for their drinking water supply. This reflects, in part, the metropolitan character of Richland County and the more rural character of Lexington County.

TABLE 5-2: ESTIMATED USE OF GROUND WATER IN SOUTHEASTERN U.S.IN 1975
(millions of gallons per day)

State	Public Supply	Rural[a]	Irrigation	Self-Supplied Industrial[b]	Total	Ground Water as a Percentage of Total Water Use[c]
Alabama, Ground water	120	74	7	160	361	
% Total supply[d]	24	79	32	12	18	4
Florida, Ground water	980	250	1,200	780	3,210	
% Total supply	85	97	43	83	62	18
Georgia, Ground water	150	69	24	550	793	
% Total supply	27	82	38	49	43	14
Kentucky, Ground water	38	38	0.1	75	151	
% Total supply	15	45	4	27	24	5
Mississippi, Ground water	180	33	550	330	1,093	
% Total supply	84	66	82	63	75	52
North Carolina, Ground water	57	190	53	250	550	
% Total supply	12	96	61	33	36	9
South Carolina, Ground water	59	73	9	54	195	
% Total supply	18	69	31	15	24	3
Tennessee, Ground water	170	47	3	150	370	
% Total supply	39	59	38	11	20	5
Southeast, Ground water	1,754	774	1,846	2,349	6,723	
% Total supply	45	81	50	35	44	12

Source: Murray, C. R. and E. B. Reeves 1977.

[a] Domestic and livestock use.

[b] Excluding use for thermoelectric power generation (93 mgd) and saline water (53 mgd).

[c] Includes water used for thermoelectric power generation and saline water.

[d] This indicates the percentage of fresh water withdrawals taken from ground water sources.

TABLE 5-3: ESTIMATED USE OF GROUND WATER IN SOUTHEASTERN U.S. IN 1980 (millions of gallons per day)

State	Public Supply	Rural[a]	Irrigation	Self-Supplied Industrial[b]	Total	Ground Water as a Percentage of Total Water Use[c]
Alabama, Ground water	160	130	9	51	350	
% Total supply[d]	26	67	27	4	13	3
Florida, Ground water	1,200	290	1,600	640	3,730	
% Total supply	88	94	53	82	68	18
Georgia, Ground water	230	150	380	400	1,160	
% Total supply	30	93	66	51	51	17
Kentucky, Ground water	47	56	0.2	130	233	
% Total supply	13	57	4	41	30	5
Mississippi, Ground water	250	37	840	360	1,487	
% Total supply	86	76	87	58	77	43
North Carolina, Ground water	70	170	39	490	769	
% Total supply	12	97	30	17	20	10
South Carolina, Ground water	78	77	17	57	229	
% Total supply	22	89	31	12	24	4
Tennessee, Ground water	200	50	6	190	446	
% Total supply	39	59	53	11	20	5
Southeast, Ground water	2,235	960	2,891	2,318	8,404	
% Total supply	46	83	60	27	41	12

Source: Solley, Chase, and Mann 1983.

[a] Domestic and livestock use.

[b] Excluding use for thermoelectric power generation (108 mgd) and saline water (43 mgd).

[c] Includes water used for thermoelectric power generation and saline water.

[d] This indicates the percentage of fresh water withdrawals taken from ground water sources.

increased dependence. This is particularly true in North Carolina where ground water use increased from 550 to 769 mgd from 1975 to 1980 but the percentage of fresh water coming from ground water resources decreased from 36 to 20 percent.

Overall, the end uses of the withdrawals changed somewhat between 1975 and 1980. Although the percentage of fresh water supply increases were not large, there were considerable increases in the amount of ground water withdrawn for public[1] (481 mgd), rural[2] (186 mgd), and irrigation (1045 mgd) uses. On the other hand, the amount of ground water withdrawn for self-supplied industrial uses decreased slightly (31 mgd) and the ground water percentage of the industrial supply decreased from 35 to 27 percent.

Dependence on fresh ground water as a source for public supplies remained about the same from 1975 to 1980; however, each of the states did increase the amount of ground water used for this purpose. In 1980, dependence on ground water ranged from lows of 12 and 13 percent in North Carolina and Kentucky respectively, to 86 percent in Mississippi and 88 percent in Florida.

Rural users are the most dependent on ground water; 83 percent of the rural supply comes from ground water sources. In no state does ground water account for less than 57 percent (Kentucky) of the rural supply. North Carolina (97 percent), Florida (94 percent), and Georgia (93 percent) are the most dependent on ground water for rural supplies. From 1975 to 1980, withdrawals declined slightly for North Carolina (by 20 mgd) and Florida (by 40 mgd), while Georgia increased withdrawals by 81 mgd. Further, the percentage of rural supplies accounted for by ground water increased from 82 to 93 percent in Georgia.

Ground water resources are important to irrigation in many areas of the Southeast. Mississippi (87 percent), Georgia (66 percent), Florida (53 percent), and Tennessee (53 percent) are the most dependent on ground water as a source of irrigation water. Although Tennessee relies on ground water for slightly over 50 percent of its irrigation supplies, only six mgd of ground water are used for irrigation in Tennessee. Florida, on the other hand, uses 1.6 bgd of ground water for irrigation.

Recently, the use of ground water for irrigation has become even more important in some states. For example, irrigation water use in Georgia has grown from almost zero in 1950 to an estimated 576 mgd in 1980 (Pierce and Barber 1981). About 66 percent, or 380 mgd, of the water used for irrigation comes from ground water resources. Most of this increase is confined to the Coastal Plain where the flatter topography and readily available water supplies have facilitated irrigation.

---

[1] "Public supplies" include domestic, commercial, and industrial uses and pertains to water withdrawn for all uses by public and private suppliers and delivered to users that do not supply their own water.

[2] "Rural uses" include domestic and livestock use. Individual families and small communities not served by a water utility are classified as rural with regard to water use.

From 1973 to 1980, the number of irrigated acres in Georgia increased five-fold, with the total irrigated area reaching just under one million acres in 1980 (Harrison and Skinner 1973-80). Wells have been the most rapidly increasing water source for irrigation and 450 new irrigation wells were added in 1980. Fewer than 1,000 wells were used in 1973, but the number had reached 3,387 by 1980 (Sullivan 1981). The capacity of most newer wells has been increasing, constituting an increasingly heavy drain on Georgia's ground water resources.

Approximately 75 percent of the state's irrigated acreage is located in the southwestern portion of the state where most wells are fed from the principal Artesian-Limestone Aquifer that underlies most of the Georgia Coastal Plain. This is one of the most productive aquifers in the U.S. Although it can become depleted during the peak irrigation season, it normally is replenished each year by local rainfall. While agricultural withdrawals of ground water in Georgia average 380 mgd for a 365-day year, most irrigation takes place during the summer growing season. The U.S. Geological Survey (USGS) estimates that during the dry summer of 1977, water was being withdrawn for agricultural purposes at the rate of 1.4 bgd (Gill 1978). There have been numerous reports of shallow domestic wells going dry when a nearby irrigator begins pumping.

Self-supplied industrial users[1] in the Southeast withdraw the second largest amount of ground water--2.3 bgd in 1980. However, this is a 31 mgd decrease from 1975 to 1980. Further, the proportion of fresh water supplies accounted for by ground water decreased from 33 to 26 percent during this period. Although Florida is the most dependent on ground water for self-supplied industrial uses (82 percent), the 640 mgd used in 1980 was 140 mgd less than the rate of use in 1975. Georgia and Alabama also experienced decreases in the amount of ground water withdrawn by these industrial users--150 mgd and 109 mgd, respectively. The other five states all had increases from 1975 to 1980 in the amount of ground water used, with North Carolina having the largest increase--from 250 to 490 mgd.

When water used by utilities for thermoelectric power generation and saline water are included for a picture of total water use, ground water only supplies 12 percent of the water used in the

---

[1] If a public supply is either not available or not used, the water is "self-supplied."

Southeast. Except for Mississippi, the percentage of total water use accounted for by ground water withdrawals remained relatively stable from 1975 to 1980. Of the states in the Southeast, Mississippi continues to rely the most heavily on ground water even though ground water as a percent of total water used decreased from 52 to 43 percent. Nevertheless, ground water use in Mississippi increased in each of the categories and total ground water withdrawn increased from 1.1 to 1.4 bgd between 1975 and 1980. In Florida and Georgia, ground water sources supplied 18 and 17 percent of the total water used in 1980; in no other state did ground water account for more than 10 percent of the total water supply.

The most important use of ground water is for drinking water. As indicated in Table 5-4, 67 percent of the population in the Southeast relied on ground water as a source of drinking water in 1970. Kentucky was the least dependent on ground water (39 percent) with all the other states relying on ground water for at least half of their drinking water supply. In Florida and Mississippi, ground water accounted for 91 and 90 percent of the drinking water.

Within the Southeast, virtually all of the rural population relies on ground water as their source of drinking water. This is because it is almost always simpler and cheaper to install a domestic well than to pipe and treat water from the nearest surface water body. Also, unless the surface source was a large lake, river, or reservoir, the supply would probably not be as reliable (U.S. EPA 1977). Only in Kentucky (88 percent) does less than 98 percent of the rural population depend on ground water. On the other hand, the percentage of the population served by public supplies that rely on ground water is much lower and more variable. Overall, about half of the population served by public supplies get their drinking water from ground water resources. Among the states, the dependence on ground water for public supplies ranges from highs of 89 percent and 85 percent in Florida and Mississippi, respectively, to 18 percent in South Carolina and 14 percent in Kentucky.

Although the Southeast has vast ground water resources that are increasingly being tapped as a source of water, it is difficult to determine accurately the trends in future use patterns. The most widely used technique for forecasting water use employs projections of population and per capita water use. Generally, water use trend projections assume that all factors that affect water use, such as employment, housing type, family income, water price, and weather will bear the same relationship to the population in the future as in the past (Boland, et al. 1980). This is a highly questionable assumption in a rapidly changing area. Milliam (1977) suggests that water use projections should be made within a context of an overall regional growth model which includes the major components of the regional economy. Economic growth projections should be related to the costs of supplying water services, and the possible

TABLE 5-4: DEPENDENCE OF POPULATION ON GROUND WATER AS A SOURCE OF DRINKING WATER, 1970

	Total		Municipal		Rural	
State	Total Population (thousands)	Percent of Total Population Relying on Ground Water	Population Served by Ground Water from Public Supplies (thousands)	Percent of Public Supply Population Relying on Ground Water	Population Served By Ground Water from Rural Supplies (thousands)	Percent of Rural Population Relying on Ground Water
Alabama	3,444	59	884	38	1,139	100
Florida	6,789	91	4,819	89	1,379	100
Georgia	4,590	70	825	38	2,376	98
Kentucky	3,219	39	304	14	936	88
Mississippi	2,217	90	1,177	85	827	100
North Carolina	5,082	60	660	25	2,374	99
South Carolina	2,591	61	221	18	1,359	100
Tennessee	3,924	51	1,194	38	805	100
Southeast	31,856	67	10,084	49	11,195	98

Source: U.S. Geological Survey 1970.

impacts of changing water resource costs upon water use requirements should be considered. This allows one to consider the influence of the high cost of developing a metropolitan or regional water supply on future use projections and growth patterns. Because of the difficulty of such a task and the uncertainties generally associated with projecting regional economies, most water use projections have been based on population projections made independently of economic projections, water resource costs, or other constraints. Thus, the accuracy and consequently the usefulness of these projections leave much to be desired.

Other uncertainties also decrease our ability to project water use trends including future acceptance of water reuse options, the success of conservation efforts, the impacts of regulatory initiatives, and the lack of complete information about the quality and quantity of available ground water resources. Further, if ground water resources are sufficiently degraded, they may not be useable and this will affect future use projections. In many areas, the uncertainties surrounding ground water pollution are substantial. For example, much more information is needed before it will be possible to determine how much of the waste going into the ground is hazardous, how widely it is dispersed, and the extent of potential health risks from exposure (National Water Well Association 1980).

Energy use and development--coal mining, oil and gas drilling, development of synthetic fuels, and power plant cooling--can have important impacts on the quality and quantity of ground water. Uncertainties about how much and what types of energy the Southeast will be using in the future add to the difficulty of making water-use projections. Trends in urban growth patterns and land management also will impact on future water use. Although the trend has leveled off, over the last several decades there has been an increasing concentration of population into cities and metropolitan areas. The more people, the greater the demand for potable water; however, more people also means more domestic garbage, industrial wastes, and land disturbed by construction. Thus, both ground water needs and potential sources of ground water pollution tend to be concentrated in the same areas. Although these examples are illustrative and not exhaustive, they do point out the problems associated with developing accurate ground water use projections.

5.2.2 Problems and Issues of Ground Water Depletion

Although dependence on ground water varies locally, in 1980 ground water in the Southeast accounted for 46 percent of the public water supplies, 83 percent of the rural requirements, 60 percent of the demand for irrigated agriculture, and 27 percent of the water for self-supplied industrial users (Table 5-3). However, the unconstrained use of an aquifer can lead to localized supply and quality problems. Ground water overdraft in some areas of the Southeast has led to: (1) the degradation of ground water quality;

(2) lowered water tables; and (3) subsidence. Each of these can reduce the amount of ground water available for use or otherwise lead to conditions that could affect population growth and industrial development. Although these problems generally are local in nature, they are becoming more pervasive.

A. Degradation of Ground Water Quality

One of the most serious problems resulting from overpumping of ground water is the degradation of the resource by the intrusion of saline water from either the sea or inland saline aquifers. Overpumping can decrease artesian pressure in an aquifer and allow the saline water to migrate into the fresh water aquifer (U.S. EPA 1979); continued withdrawal at high rates could cause the fresh water to become so saline that it is no longer potable without desalination or mixing with fresh water from some other source. This could lead to increased competition for surface water resources.

The Biscayne Aquifer is the sole source of potable water for the people living in southeastern Florida, from about Boca Raton south to the Miami area. Since local rainfall provides most of the aquifer's recharge, unusually dry years have resulted in overpumping by agricultural and domestic users, drawing saltwater into or near the well fields in the greater Miami area. During a drought in 1971, eight of Miami's wells had to be shut down because of saltwater intrusion (Carter 1976). In 1974, the salt front intruded to within 0.7 of a mile of the City of Miami well field in Miami Springs and reached the Homestead Air Force Base well field in the southeastern part of Dade County.

The Savannah and Chatham county area of Georgia has experienced large ground water withdrawals creating a cone of depression encompassing an area of hundreds of square miles. Savannah pumps an average of 76.3 mgd of ground water for municipal and industrial use. Georgia law guarantees well leaseholders the right to pump up to a maximum of 99.9 mgd (Frye 1982). In conjunction with approximately 9.7 mgd pumped by neighboring Hilton Head, South Carolina, these large withdrawals have resulted in the contamination of well fields on Parris Island, South Carolina, and on the northern end of Hilton Head Island and the movement of the salt front toward northeast Savannah (Spigner 1981; Pierce 1980).

The Corps of Engineers has been studying the problem and is working with the South Carolina Water Resources Commission and the Georgia Water Resources Management Branch to develop a workable solution acceptable to both states. Although Savannah currently uses 32 mgd of surface water and has a plant designed to treat 50 mgd, surface water in the area generally is contaminated with sediments and organic material. As long as treatment costs make it more expensive to use surface water than to pump cleaner ground water and existing access to well water is protected, both states agree that Savannah is not likely to decrease its withdrawals (Frye 1982).

Large ground water withdrawals to permit dry open pit mining of phosphate has lowered the potentiometric surface[1] over an area of more than 800 square miles in the Beaufort County, North Carolina region. Mining operations are expected to expand, possibly doubling ground water withdrawals (U.S. Water Resources Council 1978a). Potential salt water intrusion would be a threat to other ground water users in the area.

Heavy water-using industries have located in the Brunswick, Georgia, and northeast Florida areas, in part because of the abundance of water. These users are withdrawing large quantities of ground water in the Brunswick area which has resulted in highly mineralized water from a deeper level being drawn into the pumping zones (Kundell 1980). Continuing down the coast, problems due to the encroachment of brackish water exist in St. Marys, Georgia, and in Fernandina Beach and Jacksonville, Florida.

In the Georgia portion of the Suwannee River Basin, ground water is used for extensive irrigation of high-value crops and for livestock watering. Further, the amount of irrigation is expected to increase significantly (U.S. Water Resources Council 1978a). This could lead to the upward migration of brackish water with high sulfate content that would degrade the quality of the ground water in a large area of Georgia.

B. Lower Water Tables and Diminished Supply

Many states do not have laws regulating pumping rates in an aquifer and an individual operator is guided primarily by the cost of drilling a well and raising the water (U.S. EPA 1979). However, if the water in the aquifer continues to be overdrafted the water table will be lowered, resulting in higher pumping costs. For example, the cone of depression created by heavy ground withdrawals in the Savannah, Georgia and low country, South Carolina areas has resulted in higher pumping costs and, if carried to the extreme, could deplete ground water to the extent that pumping is not economical. In the Savannah area, new industrial operations that are major water users (5 mgd or more) must use surface water (Ledbetter 1980). Although surface sources are available, they are some distance from the coastal area, increasing the cost of development and transportation.

Similarly, the ground water table in northeast Mississippi and northwest Alabama has been lowered due to overpumping by municipalities and industry (U.S. Water Resources Council 1978a). Stream flows are low in this area limiting the potential use of surface water as a substitute for, or supplement to, ground water resources. Along the Gulf Coast of Mississippi, almost all domestic, municipal, and industrial water supplies are obtained from ground water sources. Generally, ground water resources are sufficient to provide ample supplies, but inadequate spacing and overpumping can jeopardize individual wells. Depletion of these sources would heighten the competition already taking place in Jackson County and other coastal counties (which are experiencing a decline in water tables and some salt water intrusion) for surface waters for municipal, industrial, and cooling water needs (U.S. Water Resources Council 1978a; Pepper and Branch 1980; Rhode 1983).

---

[1] The "potentiometric surface" is the level to which water under artesian conditions will rise in tightly cased wells.

Many of the wells near Georgetown, South Carolina, have a rated capacity of 100,000 gallons per day (gpd). The result of this pumping is a major reduction in the water level of the Black Creek Aquifer system where the water table is de-pressed more than 50 feet in some locations (compared to a reference well). The cone of depression actually extends well into Brunswick County, North Carolina, where water levels of monitoring wells are dropping about five feet per year. Some of the wells along the coast in the Myrtle Beach area have significantly diminished production during the peak summer use periods due to the lowered water table. In some areas this has resulted in pump replace-ments (greater horsepower) and the need to drill new wells. Combined with their water quality problems, this shortfall has led Myrtle Beach to begin to look for other sources of supply (Spigner, Stevens, and Moser 1977).

Agricultural demands also can impact on the availability of ground water resources for other uses. For example, when the irrigation system on a 3,000 acre farm a short distance from Albany, Georgia, is in full operation, 24 mgd are pumped from the Ocala Aquifer. The water table dropped 50 feet after two years of operation and the pumps had to be operated on a staggered schedule to reduce drawdown. At the same time, municipal and industrial uses in nearby Albany required about 45 mgd of ground water. This growing community with its increasing water needs was being affected by the combined demand on the aquifer system by agriculture, industry, and municipal uses (Ledbetter 1980).

C. Subsidence

Land subsidence may occur when large amounts of water are removed from an aquifer without adequate recharge. When the water level declines substantially, the elevation of the ground surface may drop several feet over a relatively large area. This can result in damage to structures, flooding in low-lying coastal areas, and the development of fissures and sinkholes that can allow the entry of polluted surface waters into the aquifer.

Subsidence is not a widespread problem in the Southeast, but it is becoming more pervasive in those areas overlying limestone aquifers. Florida has the biggest problem with subsidence or sinkholes, both in terms of the number of occurrences and the severity of the subsidence. Heavy irrigation by citrus and other agricultural industries and seasonal home irrigation during the warm, but dry, spring months places substantial stress on the aquifer systems. Over 200 sinkholes developed during the spring of 1981 and their occurrence is becoming more frequent (Belleville 1982).

Although subsidence problems in Georgia are not nearly as severe or widespread as those in Florida they too are occurring more frequently. Ground water levels in some areas of southwest Georgia are declining as a result of heavy ground water pumping for municipal, industrial, and irrigation use. This problem stretches into northern Florida and could develop in adjacent counties in Alabama. The aquifers are limestone and sandstone, and some overlie permeable sands. In all three states, overpumping has resulted in subsidence and limestone sinks that could allow the rapid recharge of shallow aquifers with poor quality surface water. This could result in contamination of ground water to the extent that it could not be used as a potable source, thus leading to a greater dependence on more costly surface sources (U.S. Water Resources Council 1978a; Joiner 1981).

In northwest Georgia, the limestone and dolomite aquifers are water-soluble and, over a long period of time, solution channels and caverns will form. When large quantities of water are withdrawn, the caverns may cave in, resulting in a collapse of the surface layer. Ground subsidence and sinkhole formation have been a serious problem in Cartersville, Cedartown, Kingston, Rossville, and Kensington (Kundell 1978; Pierce 1980).

Subsidence related to the dewatering and compaction of confining beds overlying the Tertiary Limestone Aquifer in the Savannah, Georgia, area has been well documented (Davis, et al. 1976; Davis 1977). Subsidence is continuing in this area but at a very slow rate. Surface subsidence also is a problem in many areas of South Carolina, including southwestern Georgetown County, the Jamestown area of Berkeley County, the Harleyville area of Dorchester County, and near Lake Marion in Orangeburg County (Spigner 1981).

Although subsidence is not widespread in the Southeast, continued overpumping could lead to additional occurrences. Further, the impacts of subsidence can be quite substantial. For example, by 1974 the ground water pumping rate in the Houston-Galveston region of Texas had reached 587,000 acre feet per year or 523 mgd. This high rate of ground water withdrawal resulted in water level declines from 1943 to 1973 of as much as 200 feet in wells completed in the Chicot Aquifer and as much as 325 feet in the Evangeline Aquifer. The declines in artesian pressures have resulted in pronounced subsidence of the land surface. The center of subsidence is east-southeast of Houston in Pasadena, Texas, where as much as 7.5 feet of subsidence occurred between 1943 and 1973. The area in which subsidence is one foot or more increased from about 350 square miles in 1954 to about 2,500 square miles in 1973. Damages in this coastal area included abandonment of an entire housing subdivision (about 400 homes), periodic flooding and increased risks from damage during hurricanes, and exposed casings for water, gas, and oil wells. Damage estimates reached more than 30 million dollars (Gabrysch 1976).

5.3 LEGAL, INSTITUTIONAL, AND POLITICAL CONSTRAINTS

Summary: The capacity of the southeastern states to manage their ground water supplies is constrained by laws and institutional arrangements designed to manage abundant rather than limited water resources. A few states still have no specific legislation directed toward ground water management. Even in states with ground water management strategies, serious ground water information gaps constrain planning efforts for developing future supplies. In areas where competition among heavy municipal, industrial, and agricultural ground water users has developed, state agencies have found it difficult to moderate the various interests and values at stake.

5.3.1 Introduction

Existing legal doctrines and institutional arrangements for managing ground water supplies in the Southeast generally reflect the influence of the historical tie between water rights and land ownership and the widespread abundance of surface and ground water throughout the region. However, as the South has experienced population and economic growth and severe impacts from recent droughts, concerns have increased about the adequacy of state approaches for making choices among competing uses, planning and coordinating with other government agencies, and integrating surface and ground water concerns. This section describes existing arrangements for ground water management in the Southeast, including recent management initiatives, the influence of federal policies, intergovernmental conflicts, and other constraints to effective management.

5.3.2 Laws and Administrative Systems for Managing Ground Water Availability in the Southeast

Water law in the Southeast developed relatively slowly, evolving from English Common Law principles to meet different geographic conditions and changing economic and social conditions. In contrast to the semiarid western states which developed the prior appropriation doctrine to allocate their scarce surface and ground water, the humid southeastern states generally applied the riparian doctrine to surface water and the American rule or reasonable use doctrine to ground water (Putt 1981).

In England, the riparian doctrine entitled all owners of land bordered or crossed by a stream to have its waters flow to them in its normal channel, undiminished in quantity or quality (Howells 1978). This "natural flow" doctrine was not well suited to the geography of eastern rivers in the U.S. that typically flowed for hundreds of miles, especially as growth along the rivers increased demands for water use. Thus, the "natural flow" doctrine gave way to the riparian "reasonable use" principle which permits upstream riparian owners full use of the water to the extent that such use does not unreasonably interfere with the reasonable use of downstream riparian owners (Howells 1978; Dewsnup and Jensen 1973). In essence, this court-made system of riparian rights is a reciprocal one in which changes in water use can be made by individuals without government approval. If disputes over reasonable uses do arise among riparian owners, they are settled in court with a jury or judge deciding what is "reasonable" based on the facts presented in the case. All of the southeastern states, except Mississippi and Florida, apply the riparian doctrine. Mississippi adopted the prior appropriation doctrine for surface waters and Florida, in some instances, has applied the correlative rights doctrine. Table 5-5 summarizes common law based doctrines as applied to the southeastern states.

Because the largest portion of conflicts brought before the courts in the East were over surface waters, early water law principles developed around those concerns rather than over ground water disputes (Putt 1981). At least four distinct legal doctrines are associated with ground water in the United States. These are:

- Absolute ownership--known also as the "common law doctrine" or the "English rule of absolute ownership." This rule presumes, unless positive evidence of an underground stream is presented, that ground water is percolating through the soil and thus belongs to the owner of the land. In most southern states, courts have tended to reject the principle of "absolute ownership" in favor of the principle of "reasonable use" (Putt 1981; Maloney, et al. 1968).

- Reasonable use--known also as the American rule. This doctrine is a slight modification of the absolute ownership doctrine and limits the withdrawing landowner's use of ground water to a beneficial purpose of reasonable relationship to the use of the overlying land. Interference with a neighbor's supply has usually been permitted if the use is beneficial and reasonable; injunctive relief has typically been available only if use was malicious or wasteful (Maloney, et al. 1968; Dewsnup and Jensen 1973).

TABLE 5-5: COMMON LAW DOCTRINES[a] OF IMPORTANCE TO GROUND WATER MANAGEMENT IN THE SOUTHEAST

	Reasonable Use (Riparian)	Prior Appropriation	Reasonable Use (Ground Water)	Correlative Rights	Reserved Water Rights
Basis of water right	Ownership of land adjoining stream or overlying underground stream.	Seniority of water rights application (first in time, first in right); ownership of adjoining or overlying land not required.	Ownership of land overlying the resource.	Ownership of overlying land.	The establishment of a federal reservation (e.g., national park, military installation, or Indian reservation) entitles the government or Indians to a sufficient quantity of unappropriated water to accomplish the purposes for which the land was reserved.
Place of use	Usually restricted to use on the riparian land.	No restriction.	Restricted to use on overlying land.	May be restricted to use on overlying land.	Restricted to use related to purpose of the reserved land.
Extent of use	Reasonable use; user may not interfere with reasonable uses of downstream riparian owners.	Specified in water appropriation; senior users may injure junior users if use is beneficial. Junior users may receive priority during severe water shortages. "Historic use" patterns may modify original rights.	Few cases of restrictions or legal accountability on overlying user who produces injury to neighboring landowners as long as the use was beneficial, not malicious.	Blends principles of riparian and ground water reasonable use doctrines; rights held so long as user does not interfere with other users; conflicts resolved through proportional division of available supplies.	Uncertain regarding reserved quantities.
Criteria for establishing preferential uses	Decided on a case-by-case basis by the courts; malicious, wasteful, or injurous use typically required for action.	Seniority clause establishing priority of rights; preference clause specifing most important uses in times of droughts or other emergencies.	None, decided on a case-by-case basis.	All users' rights are coequal before the court; in times of scarcity each user must accept a proportionate reduction in use.	Federal and Indian claims have preference over those of the states or individual users.
Effect of nonuse	None	May cause loss of rights to use water (use or lose).	None	None	None
States affected	AL, FL, GA, KY, NC, SC, TN	MS (SW only)	AL, FL, GA, KY, MS, NC, SC, TN	FL	AL, FL, GA, KY, MS, NC, SC, TN

[a] These represent common law doctrines of interest. Although the prior appropriation system is now supported in statutes, its concepts were developed at common law. Other statutory provisions for allocations of water rights (e.g., permitting systems, "capacity-use" designation, etc.) have been deliberately omitted.

- Correlative rights--a modification of the reasonable use doctrine and based on the theory of proportionate sharing of water among landowners from a common supply, especially during times of scarcity. This doctrine provides rights which are equal in priority regardless of the time they were secured and which may be based on the portion of land owned over the common source (U.S. Water Resources Center 1981).

- Prior appropriation--the state administers water allocations; rights to use water are generally awarded for beneficial use only with priority of rights established by the time of application to the state (first in time, first in right). Thus, in times of scarcity the first authorized user has priority over later appropriations (Putt 1981; U.S. Water Resources Council 1981).

When ground water disputes did arise, they were settled through the common law principle of "absolute ownership" which gave the land owner all of the water within or under the land because it was considered part of the soil. However, this was soon modified to allow the owner of land, through which the underground water was percolating, the right to draw it to the surface for reasonable use (Dewsnup and Jensen 1973). In contrast to the riparian "reasonable use" principle which is a relative concept determined by extent of injury to other parties, the ground water "reasonable use" doctrine does not usually impose restrictions or accountability on the owner and, thus, differs little from absolute ownership (Cox 1982).

The ground water doctrine most similar to the riparian "reasonable use" concept and now applied in some states to ground water is that of "correlative rights." Emphasizing the reciprocity of individual rights, the correlative rights doctrine holds that each land owner has rights to the common pool of ground water in proportion to his land overlying the pool (Dewsnup and Jensen 1973).

These doctrines, which have historically distinguished the water laws of the eastern and western regions of the U.S., are beginning to be modified as the inadequacies of both the appropriation doctrine and the "common law" doctrines have become apparent. For example, few of these doctrines deal explicitly with the issue of which uses are to receive preference in times of conflict or scarcity. The appropriation doctrine as applied in the western states does contain preference clauses specifying priorities among users in times of insufficient water regardless of the date of water right application. These preferences usually place domestic and municipal use first, agricultural use second, and industrial use third (Ballard, Devine, et al. 1982). The other doctrines, however, do not provide such a specific preference clause for emergency allocation; rather the emphasis has been on adjudication of conflicts by competing users in times of scarcity. The courts in these states have tended to treat water rights according to criteria that are responsive to the system of priorities and values within the state (Grigg et al. 1979; Kemp 1982). Although "reasonable use" is the predominant ground water doctrine in the southeastern states, their ground water laws, as well as the administrative systems to implement and enforce them, can increasingly be characterized as a mix, modified on the basis of an individual state's need rather than pure, original doctrines (Grigg et al. 1979).

The most typical modification in state ground water law for Southeastern states has been the addition of permitting requirements for large ground water users as a tool for enhancing management capacity. However, the states vary considerably in the extent to which such modifications have actually been adopted and implemented (see Table 5-6). Alabama, for example, has no statutory control over ground water use; it relies solely on the reasonable use doctrine. The pattern in that state has been to consider mining and industry as the preferred reasonable uses of land (Howells 1978).

Tennessee has no permitting requirement, but does require users drawing 50,000 gpd or more from any source to register with the Division of Water Resources. Tennessee statutes on municipal and utility use of eminent domain to condemn water rights make no distinction between ground and surface water; the Tennessee Water Pollution Control Act (1971) contains a declaration that all waters are property of the state and held in public trust; and well drillers are regulated. However, none of these have materialized into active management tools; instead, the reasonable use doctrine is generally accepted as applicable and, in the absence of widespread shortage, has not been challenged (Howells 1978).

North Carolina has instituted a permitting system which was designed to manage surface and ground water use conjunctively (North Carolina Water Use Act 1967). However such permitting was restricted to "capacity-use areas" or those areas where the North Carolina Environmental Commission found that strong water competition existed, or was developing, which would threaten or impair the renewal of state waters. Users demanding over 100,000 gpd were required to seek permits although existing pumping at the time of enactment was protected through a grandfather clause, thus reducing the flexibility of the state to deal with major users. The apparent impetus for North Carolina's regulatory system was concern over saltwater intrusion as a threat to local drinking water supplies due to overpumping in the phosphate mining region in the eastern part of the state--the only area ever designated as a "capacity-use area" (Putt 1981). The act, which had no specific authority provisions or guidelines for regulating permittees, establishing priorities among users, or handling emergencies, was included in a 1977 general sunset law on environmental programs to be effective in July 1981 . The "capacity use" law, however, has been allowed to remain in effect with only minor procedural changes (Putt 1981; Newlin 1983).

TABLE 5-6: GROUND WATER USE MANAGEMENT CAPACITY IN THE SOUTHEAST

State	Specific Legislation on Ground Water Use	Agencies Responsible for Management	Ground Water Use Planning	Designation of Capacity Use Area	Permitting
Alabama	None	Courts	None	No	None
Florida	Water Resources Act of 1972	Dept. of Environmental Regulation and 5 water management districts	Emphasizes planning at both district and state level; has a state water use plan	Five districts emphasizing conjunctive management	Permits for >100,000 gpd based on consumptive vs. nonconsumptive use
Georgia	Ground Water Use Act of 1972, Amended 1973	Dept. of Natural Resources, Environmental Protection Division (EPD)	Statewide assessment of ground water use under way	No, EPD has statewide jurisdiction to manage ground water use	Permits for >100,000 gpd; exempts agriculture
Kentucky	Water Resources Act of 1966	Dept. of Natural Resources' Division of Water; Water Resources Authority	Policy "to develop the state's ground water resources"	In emergencies, the Dept. of Natural Resources may disregard permits	Permits for >100,000 gpd; exempts agriculture & domestic
Mississippi	Ground Water Management Act of 1976	Board of Water Commissioners	Water Management Council appointed March 1983; must make recommendations to the Legislature by January 1985	Yes	Permits for >50,000 gpd; exempts oil and gas, domestic and agriculture
North Carolina	Water Use Act of 1967	Dept. of Natural Resources and Community Development	Attempting to plan for surface & ground water conjunctively	Yes	Permits for >100,000 gpd to protect ground water required in capacity use areas
South Carolina	Ground Water Use Act of 1969 Water Use Reporting and Coordination Act of 1982	Water Resources Commission	Base-line assessment of resources	Yes	Permits for >100,000 gpd in capacity use areas
Tennessee	None	Dept. of Conservation's Division of Water Resources	Task force organized	No	None; User drawing >50,000 gpd must register

South Carolina's Groundwater Use Act of 1969, based on the North Carolina statutes, essentially authorizes the South Carolina Water Resources Commission to establish, upon the request of a local unit of government, "capacity-use areas" in which permits will be required for users withdrawing in excess of 100,000 gpd. The Commission must follow established procedures for delineating such capacity use areas and, once they are established, apply the reasonable use doctrine in awarding the permits taking into consideration such circumstances as the effects of the use on other users and any prior investment in use by permit applicants (Putt 1981). The state currently has two "capacity-use areas," one in the Waccamaw Regional Planning Area, and another in the Low Country coastal area near Savannah, Georgia. The Charleston, South Carolina area is under consideration as a third "capacity-use area."

South Carolina's experience with permitting in "capacity-use areas" has been similar to North Carolina's in that no permit applications have been denied or modified in these areas. In addition, the requirement that the South Carolina Water Resource Commission wait until local units request assistance, as well as the time needed to complete studies to justify a decision to delineate an area, both serve as constraints to timely response to a potentially urgent need for the protection and management of an aquifer.

In 1976 Mississippi enacted a ground water permitting system for capacity-use areas based on the North and South Carolina legislation. It requires permits for withdrawals in excess of 50,000 gpd. However, specific exemptions are provided for oil and gas activities holding state permits and all domestic and agricultural wells constructed by individuals (Putt 1981). Kentucky essentially applies the reasonable-beneficial use principles to ground water rights with provisions (based on the Water Resources Act of 1966) for allocation of all surface and ground water resources in the state during times of emergencies without regard to existing permits (Dewsnup and Jensen 1973).

Georgia has a state-wide permitting system for ground water use (Groundwater Use Act of 1972, 1973, as amended), which requires a permit from the Environmental Protection Division (EPD) of the Department of Natural Resources for withdrawing, obtaining, or utilizing ground waters in excess of 100,000 gpd. Agricultural uses are exempt from the permitting process, although they must report monthly use once a year to the cooperative extension agent who compiles the information and forwards it to the EPD (Kundell 1983). The EPD has considerable authority to reallocate or restrict ground water use in the face of emergencies; to regulate use through timing of withdrawals, well depth and spacing, and pumping levels; and to use any measures necessary to prevent or abate the incidence of salt water intrusion.

Although Florida generally has adequate water supplies, the state has developed one of the most comprehensive permitting systems in response to water shortages and contamination problems because of the inequitable distribution of population pressures, heavy industrialization, urbanization, and rising agricultural and energy demands. The state uses a two-tiered management system. The chief administrative body is the Department of Environmental Regulation (DER), which is responsible for developing the state's water use plan and, under it, five water management districts authorized by DER to regulate water use on its behalf. In practice, these districts are relatively autonomous because their budgets are based on ad valorem taxes rather than legislative funding and because their governing board members are gubernatorial appointments. Thus, each district has control over allocation mechanisms and may choose, for example, to allow common law principles to allocate water rather than implementing a permitting system (Putt 1981).

Florida is unique among the southeastern states in focusing its permitting program consumptive and nonconsumptive uses rather than by ground and surface waters. Ownership of the land adjoining water resources (surface-riparian) or overlying (ground-absolute ownership) are no longer prerequisites for obtaining a permit for use; indeed, the Florida Supreme Court (371 So. 2d 663) ruled in 1979 that the condemnation by statute of landowners' rights to underlying ground water did not violate any common law doctrine, a constitutional issue because of the due process protection afforded property interests. The reasonable/beneficial use doctrine is still utilized by the state but is defined to include explicit consideration of economic concepts and the public interest (Putt 1981). In those states where "reasonable use" continues to be defined through common law rather than legislation, reasonable use more typically encompasses traditional, private uses of water or land and does not impose accountability on the user to any neighbor's or broader public's interest (Cox 1982).

5.3.3 State Capacity for Managing Ground Water Availability

The southeastern states have become increasingly involved in the management of ground water supplies over the past decade, primarily because their common-law systems cannot respond to shortages and resolve conflicts in a timely manner. The capacity of some states, however, to plan for and manage the development and use of ground water can be seriously constrained by lack of adequate staff, resource data, authority, or political support.

Permitting systems have typically become the major mechanism for managing ground water availability in the Southeast; yet this regulatory approach can create problems. One controversial issue is the extent to which states will actually be able to use the permitting authority to manage resources. In South Carolina, for example, the permitting authority has been specifically tied to large users (>100,000 gpd) in "capacity-use areas." Moreover, the request for designation as a "capacity use area" has to come from local units of government and must be followed by a thorough study of the area, a lengthy process which can be costly. To date, no permits have been denied, nor have any formal criteria for assigning priorities in the face of conflicting demands been established.

North Carolina has had a similar experience with one attempt to use its permitting system to control use in a phosphate mining region. In 1976, when a second phosphate mining company applied for a permit competing with that held by the original firm, North Carolina decided that the total withdrawals under both would harm the aquifer. The state's decision to reduce the withdrawals of the first company to accommodate the second resulted in litigation. In an out-of-court settlement, the state agreed to allow the company its original withdrawals and then moved to reduce the amount for the pending permit of the second company.

The law, as written, had inadequate provisions for due process or just compensation for required reductions or discontinuance in withdrawals of existing permittees. In addition, no criteria were specified for establishing priorities or preferences among competing uses or in times of drought (Howells 1978). Although these priorities may be established as discretionary decisions by administrators, such decisions would present clear opportunities for litigation which then defeats the purpose of creating crisis-management areas. Other deficiencies in the law highlighted by the state's attempt to manage the capacity use area included limited data which left the state dependent on company data, insufficient staff, uncertainty among staff over implementation responsibilities, and uncertainties over interpretations of water law (Howells 1978).

Evaluations of North Carolina's "capacity use area" approach have found it to be deficient in some ways (Grigg, et al. 1979; N.C. Legislative Study Commission 1980). No effective management measures were implemented (Sherwani 1980). Even though permits were required for withdrawals of 100,000 gpd or more, these requirements have been ones of use franchises, monitoring and reporting rather than management tools (Peek 1980).

Tennessee law requires all persons withdrawing 50,000 gpd of water or more from any source to register with the Division of Water Resources. This requirement has never been implemented, however, and funding to the Division has never been provided at a level appropriate for developing capacity to implement the requirement or the basic statutory responsibility for creating and defining the rights of users (Hunt 1980).

Giving a state agency the authority to use permits to protect and develop ground water supplies assumes that the agency has or will develop some information on the hydrological characteristics of its reservoirs or aquifers within a particular basin. Information about recharge rates, well productivity (variations in yield rates), effect of pumping rates on the depth and spread of cones of depression, and potential damage from mining, for example, should be essential to decisions to regulate water use (see Chapter 4 for a discussion of data needs).

Lack of basic descriptive data can be a considerable constraint on management capacity and the states vary considerably in the level of information which they have developed about their ground water resources. Florida, primarily because of its heavy dependence on ground water, has achieved a more comprehensive description of its ground water than have the other seven states in the study area. In contrast, states such as South Carolina, Georgia, and North Carolina have areas in the Piedmont which have remained relatively unevaluated. In these areas, incomplete ground water appraisals may limit the states' capacity to manage supplies through developing alternative water supplies and to respond to new water development needs.

South Carolina now requires all those using in excess of 100,000 gpd of water to report quarterly the amount of water used, where it is used, purpose of use, treatment given, and other technical details. This requirement provoked considerable controversy, primarily because some farmers and other interests viewed it as the first step toward water allocation. The key policy goal, however, was one of establishing an accurate inventory of water use in the state. Important influences on the passage of this bill were the beliefs that water is a public resource of vital importance, that insufficient information constrained development of effective future plans, and that a systematic coordinated program must collect information on both the ground and surface waters of the single hydrologic resource (S.C. Water Use Reporting and Coordination Act of 1982 Section 1). Farmers' concerns about eventual allocation were allayed somewhat by assurances that the best way to justify agricultural need for water in the state was through information about the actual amount used during normal growing seasons. As a compromise, farmers are allowed to report use annually, rather than quarterly, and to extension agents, rather than to the state agency.

Planning and management of ground water requires sufficient resources to manage water resources. The combination of an economic recession and changes in federal funding for water programs has left many states without the financial resources needed to do more than crisis management. Although it is not yet clear which federal programs will be picked up by states, little disagreement exists over the fact that states will be responsible for more programs with less money than before (Mosher 1982). This means that water issues will have to compete even more intensively for a share of state revenues.

In states such as Florida where water is a highly salient public issue and water district budgets are tied to ad valorem taxes, this may be less difficult than in states like Alabama where ground water issues seem not as widely discussed and financing less secure. However, most states are experiencing stressful social and economic conditions. Even if funding is available, finding trained hydrologists, geologists, and other technical support staff may prove difficult for some locations (U.S. Water Resources Council 1981) because of a nationwide shortage in some of these fields. Thus, overall resources in the form of finances and staff may create continuing problems for states as they attempt to establish water management systems.

5.3.4 Impacts of Federal Policies

The federal government has emphasized surface water development, almost to the exclusion of ground water, in its major construction programs. As of 1981, the federal government has invested over 54 billion dollars in water resources projects, mostly dams and multipurpose projects such as those of the Tennessee Valley Authority (TVA). These projects have served a variety of interests including irrigation, municipal and industrial users, hydroelectric power generators, fish and wildlife enhancement, outdoor recreation, flood control, and navigation (U.S. General Accounting Office 1982). No comparable federal program exists for ground water development.

In eastern Tennessee, for example, the TVA has long dominated water planning and management of the ground water resources. The Army Corps of Engineers has affected water resource development across the southeastern states through the construction of dams and dredging projects such as the Intracoastal Waterways and maintenance of ports, harbors, and channels.

The Farmers Home Administration in the U.S. Department of Agriculture (USDA) has also had a major impact on ground water development. Funding has been provided through that agency to help families in rural areas to develop water supplies thus making growth in rural counties possible, even where existing water and sewer services were nonexistent (North 1978). This has had an impact in southeastern states like North and South Carolina which have a large percentage of population in the rural areas and are highly dependent on ground water for drinking supplies.

Indirect effects on supplies and demand have also been created through subsidized costs to the users of water from federal projects. For example, policies regarding surface water pricing for irrigation from reservoirs have distorted water values in the West. The problems created by these federal policies include the promotion or encouragement of inefficient use of water and encouragement of increased development in water-short areas (U.S. Water Resources

Council 1977). Federal energy policies have also affected the water requirements and consumption for various energy or industrial facilities (e.g., wet vs. dry cooling for power plants) (U.S. Water Resources Council 1981).

The existence or expansion of federal facilities, such as military bases and parks or wildlife refuges, often impact local water policy. They not only may create new demands on existing supplies, but also may raise the issue of the "reserved rights doctrine" through which the federal government may establish its rights to as much water as it needs to accomplish the purpose of the facility or base. In times of scarcity, the federal government has some legal precedence for claiming its exemption from state management plans (Ballard, Devine, et al. 1982). For example, the Everglades National Park has certain requirements for the amount of water that must be supplied to the park, thus affecting the amount of water available for other users in South Florida (Yoder 1982).

Not all federal policies have emphasized surface water to the exclusion of ground water. The USGS, for example, has been successful in working with the states to establish information to be used in improving development and management of ground water resources. Cooperative research projects on ground water problems with joint or matching funding have been undertaken by the USGS and the states. Clair Guess (1978), Executive Director of South Carolina's Water Resources Commission has said that the USGS "...has been a strong arm in developing a systematic method cooperatively with us in seeking more and additional ground water information as a viable data base from which to climb."

Current efforts by the Reagan Administration to reduce federal involvement in the management and planning of water resource development reflect, in part, the intent to pressure states to take the lead in managing allocation of water resources. For example, the Department of Interior is actively considering a policy which would require the states to pick up about 30 to 35 percent of the cost of federal water developments, even though several years ago the states rejected a Carter Administration Plan to charge 10 percent of the cost (Schmidt 1982). The concern over the fragmentation of national water policy in the past is supported by the range of agencies involved directly or indirectly in water policy, including groups within the Department of Interior, USDA, Army Corps of Engineers, TVA, EPA, Department of Housing and Urban Development, and the Council of Environmental Quality.

In light of federal budget cuts, efforts by the Reagan Administration to increase the state share of water project costs, and the increasing state and local interest in managing ground water resources, it seems the federal role may gradually become more restricted. For example, limited levels of technical assistance in the form of data collection by the USGS, informational research on such issues as improving efficiency of irrigation and pumping strategies, and dissemination of information are likely strategies for federal assistance with ground water issues. In addition, federal surface water projects are now explicitly required to consider possible impacts on ground water resources during evaluation stages, a policy development recognizing the relationship between surface and ground water in most areas of the U.S. (Seinwell 1980).

5.3.5 Intergovernmental and Jurisdictional Conflicts

Ground water management, as well as management of surface water, has traditionally been the states' responsibility except where federal lands exist with reserved rights (e.g. primarily the West) or where navigable waters or interstate commerce are involved. Where ground water development problems extend across political boundaries, such as state lines, greater efforts at cooperation are needed to coordinate management of ground water supplies.

In contrast to the western states which have a number of interstate compacts allocating the water in shared river basins (e.g. the Colorado and the Missouri), the southeastern states have no formal agreements of this type. Traditionally, southeastern states have allowed conflicts to be resolved through common law principles, favoring individual land owners' vested rights, such as the reasonable use doctrine which has been interpreted differently from state to state through time. Even attempts to divert or transfer water within a state from one watershed or area to another are restricted by these common law doctrines of the Southeast which tie rights to use ground or surface water to the overlying or adjoining land.

The Low Country, a predominately rural and resort area in coastal South Carolina, for example, has experienced declining water tables--as much as ten feet in Colleton County and more than 100 feet in southern Jasper County. Most of this drawdown is attributed to the heavy use of the area's principal artesian aquifer in the Savannah, Georgia, area and withdrawals on Hilton Head Island, South Carolina. The City of Savannah and nearby industries have been pumping at the rate of about 76 mgd. Because surface waters in most of the Low Country are either too salty or undependable to be used for drinking water supplies, the potential implications of overdevelopment of ground water for these communities are particularly serious (Hayes 1979). Under the sponsorship of the U.S. Army Corps of Engineers, an executive committee composed of water resource officials from Georgia and South Carolina is currently working on defining the problem and developing a workable management plan.

A similar issue exists along the border of North Carolina and Virginia where North Carolina has experienced a 10-foot lowering of the water table over a large area. Most of the withdrawals have been in the Franklin, Virginia, area. An informal interstate committee has been established to identify issues and alternatives for resolving emerging conflicts (Howells 1978). Alternatives such as litigation or federally imposed solutions may make compromise and negotiation more attractive. However, an important issue raised by these types of interstate efforts is the extent to which each party is willing to impose restraints on its own economic development potential and current population needs by curtailing ground water use. This type of planning between states requires a long-range perspective, a capacity often not well-developed in state agencies.

The need for interbasin and interjurisdictional transfers of water within a state contradicts the "conventional wisdom" about the abundance of water in the South Atlantic and Gulf (Putt 1981; Grigg, et al. 1978). This issue has created conflicts between local jurisdictions or districts within states, between adjoining states and between the federal and state agencies responsible for water resource development.

Municipalities in the Southeast, for example, have not normally been favored by the courts in establishing water rights and, thus, have found themselves competing with heavy users such as agriculture and industrial and energy developments which have the ability to pay the high costs of pumping water from low pressure or deep wells. This contrasts with the western states where preference clauses typically specify that, in times of drought or other emergencies, municipal needs are to receive priority over industrial and agricultural uses (Ballard, Devine, et al. 1982; Kemp 1982).

In cities where water shortages exist, inadequate supplies must be enhanced through transfers or seeking rights to ground water supplies outside of the immediate political jurisdiction where population, municipal development, and industrial investment are sufficiently high to make such a solution essential. Florida provides perhaps the best example of this mismatch between supply and demand. The Southwest Florida Water Management District which includes Tampa-St. Petersburg, one of the fastest growing cities in the U.S., is considering the possibility of diverting water from the Suwannee River in the Suwannee River Water Management District to the Tampa Bay area. While interbasin transfers within a particular management district of Florida have been common, no large-scale transfers between any districts have been accomplished (Kemp 1982).

These districts operate independently based on their own self-developed water use plans, thus, the standards and guidelines for issuing permits differ widely based on district interpretations of the general legislative criteria. While the Florida Department of Environmental Regulation (DER) has the authority to modify or alter district plans, it has not yet done so and is unlikely to want the job of resolving the conflicting "public interests" of the two districts. Moreover, one evident impact of the Suwannee River transfer would be an immediate drop of the ground water table at the point of diversion with subsequent saltwater intrusion (Kemp 1982). Ironically, such intrusion is not one of the factors considered under statute by DER when making regulatory decisions on pollution control--thus the districts must handle that problem.

The federal government through its Army Corps of Engineers could become involved through its jurisdiction to require federal permits for activities affecting navigable waters (Kemp 1982). Thus, individuals with existing water rights under common law principles, the municipal governments in the Tampa Bay area, two local water management districts, the state of Florida, and the federal government all play a role in this transaction and likely all reflect differing interests and values.

5.3.6 Constraints to Managing Ground Water Availability

State and local governments in the Southeast have increasingly made a choice to become involved in managing the supplies of ground water rather than leaving allocation choices solely to the private sector. Once this decision is made, however, public officials must establish goals, objectives, and criteria for allocation, and then choose among a variety of management and technical options for accomplishing allocation. These choices are often constrained by the existing legal or regulatory framework, lack of political support among key constituencies for change, and uncertainty about the effectiveness of specific regulatory approaches.

The lack of clear objectives or specific guidelines for regulation of ground water allocation, in conjunction with continuing application of vaguely defined common law principles throughout the Southeast, has created considerable uncertainty for both managers and users of water resources. Economic issues, such as the appropriate length of time to award secure water rights in order to encourage efficient use of ground water and what type of uses may require a longer time period with secure rights than others, are still unresolved (Grant 1981; Trelease 1974). Most permit systems in the Southeast, for example, grant rights to use water for a maximum of either 10 or 20 years or for a period over which the user's investment can be amortized. At the end of that time period, the user risks losing water rights.

Legal issues, such as the interpretation of reasonable/beneficial use standards or the requirement for due process in permitting and transferring water rights, are also unresolved. In the case of ground water-use conflicts, the courts may be asked to make decisions for which no clear-cut legal precedents exist. In South Carolina, for example, the Supreme Court has never heard a case involving conflicts over ground water use. Yet courts are the major institution for administration of water rights in the Southeast through conflict resolutions on a case-by-case basis. Even in states which have administrative arrangements for allocation, efforts to set priorities among users typically result in immediate court challenges based on common law principles (Sherwani 1980).

The same vested interests which have supported the existing system of tying water rights to property as a protection against state regulation have worked to block legislation which would alter the existing water rights system (Snyder 1973; Putt 1981; Dewsnup and Jensen 1973; and Murphy 1970). Therefore, courts continue to decide issues on a case-by-case basis, traditionally limiting rulings to the narrow question raised by the particular parties before the court. Such incremental rulings based on legal precedent, rather than current or anticipatory issues, create barriers for those who must meet rapidly changing demands for water resources. The courts also must rule based on existing common law doctrines and legislation even if they don't believe it to be entirely adequate. For example, if it could be proven in court by a complainant that underground water was flowing in an underground stream or well defined channel, then the land owner's rights were held to the riparian doctrine applied to surface waters (Maloney, et al. 1968). However, some states limited use of such streams to the quantity needed for a useful purpose of the overlying land and restricted waste or export of water for uses not related to the land (Howells 1978). In addition, outdated scientific/technical concepts about ground water and restrictive definitions of water rights are now rooted in both legislation and legal precedents which guide the courts.

Concerns over efficiencies in water use have increased the attractiveness of conservation as a management strategy. Conservation of water supplies has typically been viewed as a short-term solution to occasionally severe drought or contamination episodes. The long-range impacts of rapid population growth, energy development, and increasing irrigation, however, have created some interest in conservation as a means of managing water supply and demand more efficiently. Although significant improvements in municipal delivery systems (e.g. leaky pipes, lines, etc.) and home conservation efforts were assumed to be forthcoming by the U.S. Water Resources Council (1978b), these have not been extensive both because of the tight financial squeeze utilities are experiencing now and the lack of education and incentives provided for citizens.

Examples do exist throughout the Southeast, however, of efforts to implement and evaluate conservation programs. For example, Florida and Georgia now require all new construction in the state to use water conserving shower heads and water closets (Florida DER 1982). The South Florida Water Management District (SFWMD) has begun implementing a plan with specific water restrictions or conservation targets for all users during periods of water shortage. Actions to tie the unit price of water more directly either to actual costs or to conservation goals have been initiated by some utilities in the Southeast. Techniques such as leak detection and repair for major problems, overall pressure reduction, and improved distribution systems have been used as well. These options have been favored in the past by water managers because they allow the municipality to maintain more predictable revenues. The extent to which varying options for conservation are currently hampered by such factors as inadequate budgets or lack of support by government officials and citizens for new water pricing policies is an important issue.

Most southeastern states then have legal and regulatory systems in place which do not provide the comprehensive authority required to manage ground water and surface water conjunctively, despite widespread recognition of the need for such an approach. These systems continue to recognize the often conflicting principles of property rights and the public interest in allocating supplies, creating uncertainty and restricting the states' ability to develop and protect state waters. Lastly, they fail to provide the kind of incentives and sanctions necessary to make water management economically, socially, and politically viable.

5.4 SUMMARY

Ground water has become a critical natural resource in the Southeast:

- From 1960 through 1980 ground water use increased by 160 percent and by 1980 it supplied 41 percent of the fresh water supplies not used for energy production;
- Ground water supplies about two-thirds of the region's drinking water;
- Mississippi (77 percent), Florida (68 percent), and Georgia (51 percent) are the most dependent on ground water resources as a source of supply;
- Over 80 percent of the rural supply for domestic use and livestock watering comes from ground water; rural users in North Carolina, Florida, and Georgia are almost totally dependent on ground water; and
- Ground water is an important source for irrigation uses in many states--Mississippi (87 percent), Georgia (66 percent), Florida (53 percent), and Tennessee (53 percent).

As the Southeast has grown in population and economic activity, three types of physical problems have emerged--degradation of quality, lowered water levels, and subsidence. Ground water quality degradation by salt and brackish water intrusion has become a serious problem in many South Atlantic and Gulf Coast locations, including much of Florida's coastal area, the Savannah and Brunswick areas of Georgia, and Beaufort County, North Carolina.

Localized problems with lowering of ground water levels have increased within the last five years. This has lead to higher pumping costs and the potential for impacts on economic and population growth. This particularly has been a problem in the Savannah, Georgia, and South Carolina low country areas, northeast Mississippi and northwest Alabama, in the area around Georgetown, South Carolina, and in Brunswick County, North Carolina. Further, overpumping in some areas is an interstate problem. For example, South Carolina and Georgia are working together to develop a plan to control pumping of ground water along their shared border at the coast. Similarly, Virginia and North Carolina share overpumping problems at a central point along their border. Other states with joint concerns are Georgia and Florida, and Alabama and Mississippi.

Although subsidence has not become a pervasive problem in the Southeast, many localized areas, including portions of northwest, southwest, and northeast Georgia, central and northern Florida, southern Alabama, and southeastern South Carolina have had occurrences of subsidence. If ground water overdraft continues at a high rate, subsidence and the problems associated with it could increase in many areas of the Southeast.

Even though ground water overdraft and availability problems are not likely to reach the crisis level in large areas of the region, they are becoming more widespread and can be quite serious at the local level. Further, some areas--for example, the Savannah, Georgia/southeast South Carolina area, southwest Georgia, and portions of Florida--are experiencing multiple impacts from ground water overdraft. In the long term, the problems of ground water overdraft can affect the growth and development of some areas of the Southeast. For example, historically, the water users in south Florida told the South Florida Water Management District how much water was needed to supply user needs. Now the District tells south Florida how much water it will get and the cities have to plan for growth and development accordingly.

Most ground water availability and overdraft problems in the Southeast are the result of seasonal dry periods or occasional extended droughts and do not result from a general shortage of water supplies. Strategies and techniques that will help control demands for water during times of drought (Section 7.4) and alternatives for maintaining supplies adequate to meet these demands (Section 7.3) are required to deal with these problems. However, state initiatives to exert more control over ground water resources are constrained by laws and institutional arrangements designed to manage abundant rather than limited water resources. Thus, for most states of the Southeast, management of ground water is limited to permitting requirements for users of large amounts of ground water. Such permitting requirements can be limited to small capacity use areas (North Carolina) or can exempt agriculture (Kentucky, Mississippi, Georgia), domestic (Kentucky), or oil and gas uses (Mississippi).

Four states in the Southeast have designated capacity use areas (North Carolina, Florida, Mississippi, South Carolina). However, except for Florida and Georgia, information about ground water resources generally is inadequate, and southeastern states have minimal planning activities devoted to ensuring that permits to use ground water are linked to overall development, management, and resource protection plans. Except for Florida and Georgia, the southeastern states do not have a well-developed management framework which provides authority to manage ground and surface waters conjunctively. However, the other states have established some type of study group or commission to make recommendations regarding state ground water management. Section 7.2 discusses modifications to existing ground water laws that would be necessary for more comprehensive ground water management in the Southeast, while sections 7.3 and 7.4 describe alternatives for increasing available supplies and managing demand.

REFERENCES

Ballard, Steven C., Michael D. Devine, and Associates. 1982. Water and Western Energy: Impacts, Issues and Choices. Boulder, CO: Westview Press.

Belleville, Bill. 1982. "Immediate Action Needed to Head Off Florida Water Crisis." The Christian Science Monitor (March 3): 16.

Boland, John J., Philip H. Carver, and Charles R. Flynn. 1980. "How Much Water Supply Capacity is Enough?" American Water Works Association Journal 72 (July): 368-74.

Carter, Luther J. 1976. "Dade County: The Politics of Managing Urban Growth." Science 192: 982-85.

Cox, William E. 1982. "Water Law Primer." Proceedings of the American Society of Civil Engineers 108 (March): 107-22.

Davis, G. H. 1977. "Potential for Land Subsidence Due to Reduction of Artesian Head in the Atlantic Coastal Plain." In Proceedings of the 25th Annual Hydraulics Division Specialty Conference on Hydraulics in the Coastal Zone, 152-160. New York: American Society of Civil Engineers.

Davis, G. H., H. B. Counts, and S. R. Holdahl. 1976. "Further Examination of Subsidence at Savannah, Georgia, 1955-1975." In Proceedings of the Anaheim Symposium, 347-54. Publication no. 121. Reading, Berks., Engl.: International Association of Hydrological Sciences.

Dewsnup, Richard, and Dallin W. Jensen. 1973. A Summary-Digest of State Water Laws. Washington DC: Government Printing Office.

Federal Register. 1982. (July 26): 32274.

Florida Supreme Court. 1979. 371 So. 2d 663.

Florida's Environmental News. 1982. 4(May).

Frye, Bill. 1982. "Water Negotiations Leave State Wary." Out-of-Doors 9 (December): 1,8.

Gabrysch, R. K. 1976. "Land-Surface Subsidence in the Houston-Galveston Region, Texas." In Proceedings of the Anaheim Symposium 16-24. Publication no. 121. Reading, Berks., Engl.: International Association of Hydrological Sciences.

Georgia Groundwater Use Act of 1972, 1973 as amended.

Gill, Harold E. 1978. Presentation at Georgia Water Resources Information Exchange 1978, April 4.

Grant, Douglas L. 1981. "Reasonable Groundwater Pumping Levels Under the Appropriation Doctrine: The Law and Underlying Economic Goals." Natural Resources Journal 21 (January): 1-36.

Grigg, Neil S., et al. 1979. "Evolving Water Law Needs for the Southeast U.S." In Legal, Institutional and Social Aspects of Irrigation and Drainage and Water Resources Planning and Management, 21-27. New York: American Society of Civil Engineers.

Guess, Clair P. 1978. "The Impact of Ground Water on Regional Development: A Case History." In Proceedings of the 11th Annual South Carolina Governor's Conference on Water Resources 96-100. Columbia: South Carolina Water Resources Commission.

Harrison, K. A., and R. F. Skinner. 1973-80. Irrigation Surveys. Athens: University of Georgia, Cooperative Extension Service. Published annually.

Hayes, L. R. 1979. The Groundwater Resources of Beaufort, Colleton, Hampton, and Jasper Counties, South Carolina. Columbia: South Carolina Water Resources Commission.

Howells, David H. 1978. A Summary Report: Southeast Conference on Legal and Administrative Systems for Water Allocation and Management. Raleigh: North Carolina State University, Water Resources Research Institute of the University of North Carolina.

Hunt, Robert A. 1980. "Ground Water Management in Tennessee." See Warman 1981, 84-90.

Joiner, Thomas J. 1980. "Ground Water Management Programs in Alabama." See Warman 1981, 1-11.

Kemp, Deborah J. 1982. "Interbasin Transfers of Water in Florida: Common Law and the Water Resources Act." Florida Bar Journal 56 (January): 9-21.

Kundell, James E. 1978. Ground Water Resources of Georgia. Athens: University of Georgia, Institute of Government.

______. 1980. "Georgia's Water Resources." In *Georgia Water Resources: Issues and Options*, edited by James E. Kundell, 2-16. Athens: University of Georgia, Institute of Government.

______. 1983. Science and Technology Associate, Institute of Government, University of Georgia, Athens. Letter, March 22.

Ledbetter, J. Leonard. 1980. "Developing Georgia's Coordinated Water Management Program--Surface, Ground, Quantity, and Quality." Paper presented at American Water Resources Association's Unified River Basin Management Symposium, Gatlinburg, TN, May 5.

Lowe, John S., Lon C. Ruedisili, and Bruce N. Graham. 1979. "Beyond Section 858: A Proposed Ground Water Liability and Management System for the Eastern United States." *Ecology Law Quarterly* 8: 131-61.

MacKichan, K. A., and J. C. Kammerer. 1961. *Estimated Use of Water in the United States, 1960*. Geological Survey Circular 456. Washington, DC: Government Printing Office.

Maloney, F., S. Plager, and F. Baldwin. 1968. *Water Law and Administration--The Florida Experience*. Cited in Putt 1981.

Milliman, Jerry. 1977. "Water Supply Planning and the Long-Term Outlook for Southeast Florida." *The Florida Outlook* (2nd Quarter): 23-29.

Murphy, Earl Finbar. 1970. "Regulating Ground Water in Humid Zones." In *Contemporary Developments in Water Law*, edited by C. W. Johnson and S. H. Wells, 55-71. Austin: University of Texas, Center for Research in Water Resources.

Murray, C. R., and E. B. Reeves. 1972. *Estimated Use of Water in the United States in 1970*. Geological Survey Circular 676. Washington, DC: Government Printing Office.

______. 1977. *Estimated Use of Water in the United States in 1975*. Geological Survey Circular 765. Washington, DC: Government Printing Office.

Mosher, Lawrence. 1982. "Reagan's Environmental Federalism--Are the States up to the Challenge?" *National Journal* 14 (January 30): 184-88.

National Water Well Association. 1980. "Groundwater Outlook: No Guarantees." In *Groundwater Protection*, edited by Joseph A. Davis, Washington, DC: Environmental Protection Agency.

Newlin, Jim. 1983. Staff, North Carolina State Legislature. Telephone conversation, May 12.

North Carolina. Legislative Research Commission. 1981. Management of Waste and Other Environmental Programs: Report to the General Assembly of North Carolina. Raleigh, NC: The Commission.

North Carolina. Legislative Study Commission. 1980. Alternatives for Water Management: Report to the North Carolina General Assembly. Raleigh, NC: The Commission.

North, Ronald M. 1978. "The Changing Federal Role in Financing Water Resource Development." In Proceedings of the 11th Annual South Carolina Governor's Conference in Water Resources, 73-83. Columbia: South Carolina Water Resources Commission.

Peek, Harry M. 1980. "Ground Water Program, Problems, and Needs in North Carolina." See Warman 1981, 42-58.

Pepper, Jack W., and Charles T. Branch. 1980. "Mississippi Programs Related to Ground Water Management." See Warman 1981, 38-41.

Pierce, Robert R. 1980. "Interstate Cooperation: Ground Water Problems." In Georgia Water Resources: Issues and Options, edited by James E. Kundell, 80-82. Athens: University of Georgia, Institute of Government.

Pierce, Robert R., and Nancy L. Barber. 1981. Water Use in Georgia, 1980: A Preliminary Report. Atlanta: Georgia Department of Natural Resources, Environmental Protection Division.

Putt, Larry O'Neill. 1981. "An Analysis and Evaluation of Water Rights in Alabama in Perspective with Other States in the South Atlantic and Gulf Region." Cumberland Law Review 12:92-97.

Rhode, Cy. 1983. Chairman, Mississippi Chapter, Sierra Club. Letter, April 11.

Schmidt, William E. 1982. "Plan to Share Water Project Costs is Gaining in West Under Reagan." New York Times (September 12): 1.

Seinwell, Gerald D. 1980. "National Policy for Groundwater Management." See Warman 1981, 73-83.

Sherwani, Jabbar K. 1980. Public Policy for the Management of Ground Water in the Coastal Plain of North Carolina. Raleigh, NC: Water Resources Research Institute of the University of North Carolina.

Snyder, Stephen E. 1973. "Ground Water Management: A Proposal for Texas." Texas Law Review 5: 289-317.

Solley, Wayne B., Edith B. Chase, and William B. Mann. 1983. Estimated Use of Water in the United States in 1980. Geological Survey Circular 1001. Washington, DC: Government Printing Office.

South Carolina Groundwater Use Act of 1969.

South Carolina Water Use Reporting and Coordination Act of 1982.

Spigner, B. C. 1981. "An Overview of Ground Water Management in South Carolina." See Warman 1981, 59-72.

Spigner, B. C., Ken Stevens, and W. C. Moser. 1977. Report on the Ground Water Resources of Horry and Georgetown Counties, South Carolina; A Ground Water Capacity-Use Investigation. Columbia: South Carolina Water Resources Commission.

Sullivan, G. D. 1981. "The Impact of Drought." Economic Review (September): 26-31.

Trelease, Frank J. 1974. "The Model Water Code, the Wise Administrator and the Goddam Bureaucrat." Natural Resources Journal 14 (April): 207-29.

U.S. Environmental Protection Agency (EPA). Office of Water Supply and Office of Solid Waste Management Programs. 1977. The Report to Congress: Waste Disposal Practices and Their Effects on Ground Water. Washington, DC: Environmental Protection Agency.

_______. Water Planning Division. 1979. Water Quality/Water Allocation Coordination Study: A Report to Congress in Response to Section 102(D) of the Clean Water Act. Washington, DC: Environmental Protection Agency.

U.S. General Accounting Office. 1982. Water Issues Facing the Nation. Washington, DC: Government Printing Office.

U.S. Geological Survey. Water Supply Division. 1970. Unpublished data cited in U.S. Environmental Protection Agency 1977.

U.S. Water Resources Council. 1977. "National Water Resources Policy Study: Working Draft of the Water Conservation Task Force Report, November 7."

_______. 1978a. The Nation's Water Resources 1975-2000. Vol. 4, South Atlantic-Gulf Region. Second Natoinal Water Assessment. Washington, DC: Government Printing Office.

______. 1978b. The Nation's Water Resources 1975-2000. Vol. 1, Summary. Second National Water Assessment. Washington, DC: Government Printing Office.

______. 1981. "Report of the Interstate Groundwater Management Task Force" (draft). September.

Warman, James C., ed. 1981. Ground Water Management: Proceedings of a Southeast Regional Conference. Auburn, AL: Auburn University, Water Resources Research Institute.

Yoder, Douglas. 1982. Comments from Science and Public Policy Program Ground Water Workshop, University of Oklahoma, October 28-29.

CHAPTER 6

PROTECTING GROUND WATER QUALITY

6.1 INTRODUCTION

Sources of ground water contamination and resultant water quality problems in the Southeast have been discussed in Chapter 4 of this report. These water quality problems have intensified during recent decades because: (1) sources of ground water contamination are more prevalant, (2) a larger population of ground water users exists, and (3) use of ground water is more intensive, especially in coastal areas. These factors, combined with increased awareness by the public and policy makers, have placed ground water quality problems on the current policy agenda.

Several specific problems have been identified in chapters 3 and 4 which may require changes or refinements in state or federal ground water protection policies. These include:

- Septic tanks are in widespread use in most southeastern states, with little or no regulation governing maintenance. Septic tanks are sometimes located in or just above the water table that is utilized as a drinking water source.

- Intensive applications of fertilizer are related to elevated nitrate levels, and pesticides applications are possible sources of organic contaminants found in ground water.

- Runoff in urban and rural areas can have higher levels of contaminants, including heavy metals; concentrations of some contaminants can be up to 50 times in excess of those found in raw sewage.

- Improper disposal of hazardous wastes has been identified as a major source of ground water contamination. Several technical and institutional problems exist, including uncertainty over the long-term integrity of pond liners, exclusion of small generators from RCRA regulations, sparseness of land disposal sites in the Southeast, and the magnitude of cleanup required for old hazardous waste dump sites.

- Many states in the Southeast do not have standards for maintaining aquifer quality or any established system of priorities for aquifer protection.

- Few agreed-upon criteria exist for evaluating the potential to restore polluted aquifers. Frequently rehabilitation efforts are inadequate and aquifers are abandanded.

Two categories of management options are identified in this chapter (Table 6-1): (1) regulation of pollution sources; and (2) management of aquifers. Source control includes options for reducing ground water pollution originating from sources such as septic tanks, agricultural activities, urban and suburban runoff, mining and energy extraction, and solid waste and hazardous materials handling and disposal. The management of aquifers discusses standard setting and rehabilitation approaches such as aquifer classification systems and technical approaches for cleaning up already polluted aquifers.

This chapter is intended neither to discuss all possible ground water quality protection strategies available to federal, state, and local governments nor to evaluate any given policy option in great detail. Rather, the chapter identifies and describes 21 policy options applicable to the Southeast; some of these options are only briefly identified while others are described and discussed more fully. Criteria used to select the list of options include judgements that they: (1) respond to identified problems in the Southeast; (2) raise questions or address problems in the current policy system and are potentially useful to at least several southeastern states; and (3) have received only limited attention or have been adopted by only a few states in the nation.

An example of policies identified but not discussed in detail is improved agricultural practices. Technical means known as "Best Management Practices" (BMPs) available to farmers and ranchers have been investigated in each state through EPA's 208 program (now largely inactive) and through the Department of Agriculture's Soil Conservation Service. Although BMPs can be important for protecting ground water quality, it is not the intent of this chapter to provide a detailed discussion of such programs where they have already received widespread attention.

Other chapters in this report also discuss alternatives for protecting ground water quality. Policies discussed in Chapter 8 include land use controls to protect aquifers and monitoring and data management needs. Chapter 9 addresses options to improve the organizational and administrative framework for ground water resource management, including integration of ground water quality and use management.

TABLE 6-1: GROUND WATER QUALITY POLICY OPTIONS

Objective	General Area	Specific Option
Regulate sources of pollution	6.2 Septic Tanks	1. Improved technologies
		2. Control septic tank cleaners
		3. Centralize drinking water supplies
		4. Manage land use
		5. Improved septic tank codes
	6.3 Runoff Controls	6. Agricultural controls
		7. Urban and suburban controls
	6.4 Energy and Mineral Production	8. Noncoal mining controls
		9. Improved controls in the petroleum industry
	6.5 Hazardous Waste Facility	10. Hazardous waste collection and storage services
		11. Local or state manifest system
		12. Local siting authority
		13. Centralized state authority
Manage Aquifers	6.6 Establish Standards for Ground Water Quality Management	14. Effluent standards
		15. Permits for ground water discharge
		16. Nondegradation strategy
		17. Ambient numerical standards
		18. Aquifer classification
	6.7 Rehabilitate Aquifers	19. Abatement
		20. Cleanup
		21. Restoration

6.2 SEPTIC TANKS

As discussed in Chapter 4, septic tanks are an important concern for ground water quality because they discharge more wastewater directly into ground water than any other source and they are the most frequently reported sources of bacterial and viral contamination (Council on Environmental Quality 1981; Burmaster and Harris 1982). Several problems and issues were identified, including:

- High density of septic tanks in some areas which can overload the capacity of the subsurface to remove pollutants;

- Improper siting of septic tanks (e.g. location in areas with inadequate soil types or where the drainage field is too close to drinking water wells);

- Use of chemical septic tank cleaners which contain toxic compounds; and

- Improper maintenance of septic tank systems.

Table 6-1 lists five policy options for reducing the threats to ground water quality from septic tanks. The last, improved septic tank codes, is discussed in some detail later in this section. The other four are described only briefly.

6.2.1 Improved Technologies

Improved technologies for septic tank systems can include multiple drainage fields and septic tank-mound systems. With multiple drainage fields (also known as alternating bed systems) one would, for example, have three drainage fields with each having 50 percent of the needed capacity. At any one time, only two of the drainage fields would be in operation while the third is alternated into service every 3-6 months. This serves two purposes: first, the soils under the resting field are allowed to rejuvenate by draining and re-aerating; and second, the third field serves as a back-up should one of the other drainage fields fail. Such systems may be especially important for large septic tank systems serving commercial establishments and clusters of dwellings (see Otis 1978; Canter, et al. 1983). Septic tank mound systems, developed largely in Wisconsin, are intended for areas with natural soils that are inadequate for septic tank systems (see Canter, et al. 1983). The mound system is essentially an elevated soil absorption system (see Figure 6-1). The effluent flows through the fill material where it is purified before entering the natural soil. This system offers several advantages including:

- The topsoil can be selected to be more permeable than the subsoil;

- A smaller absorption area is required for a given quantity of wastewater; and

- Nitrate nitrogen leaving the system is reduced by bacterial denitrification.

Disadvantages of septic tank mound systems include increased costs due to the cost of the fill material and its placement, and changes in the landscape.

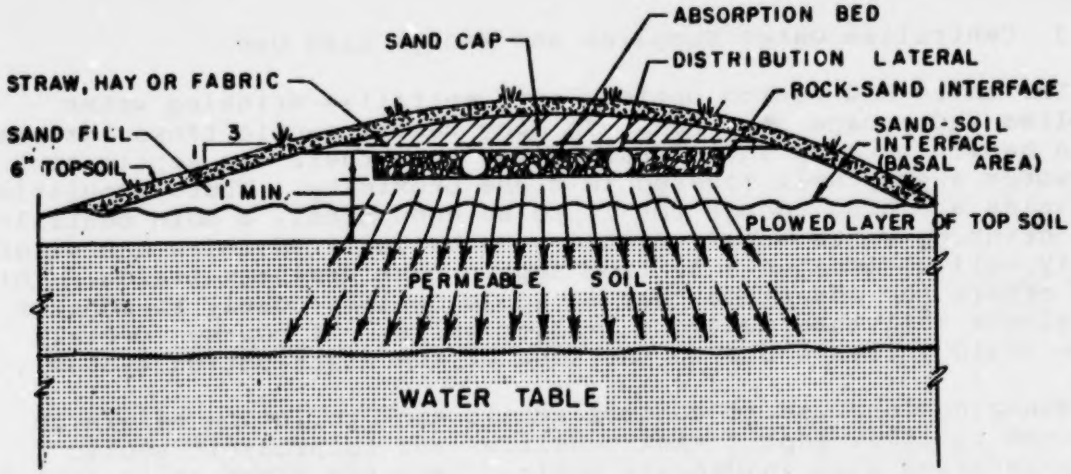


Figure 6-1: A cross-section of a septic tank mound system for on-site disposal.

Source: Moore, Gardner and Associates (n.d.)

6.2.2 Septic Tank Cleaners

Control of septic tank cleaners is an option to deal with the increased potential of ground water pollution caused by these products. As described in Chapter 4, ground water quality is threatened by these products for two reasons: (1) they dissolve sludge (which otherwise would either remain in the tank or be biologically decomposed) and discharge the effluent to ground water; and (2) the chemical product itself may contain toxic compounds (such as TCE). There is some question as to whether these products are really necessary if septic tanks are designed, installed, and operated properly; for example, sludge should be periodically pumped out and disposed of safely, not dissolved and discharged to ground water. Before any specific actions are taken in implementing this option, further research is needed to evaluate the risks and benefits of using septic tank cleaners and to evaluate alternative implementation strategies should the findings indicate that the risks outweigh the benefits. Strategies for implementing this option could include public education programs to inform potential users of the risks associated with septic tank cleaning and thus discourage their use or a prohibition on sales. Implementation of similar regulatory controls on phosphates (such as banning their use) has been successful in states such as Michigan, Wisconsin, and New York (Shogren 1983).

6.2.3 Centralize Water Supplies and Manage Land Use

The third and fourth options are centralize drinking water supplies and manage land use. In many cases, septic tanks threaten human health because individual houses have their own septic tank and water supply well located in close proximity. Where population densities are high enough for it to be economical, a more centralized drinking water supply system can be utilized, with the water supply well(s) located away from septic tank drainage fields. This also offers the advantage that it would be less costly to monitor the single well than numerous smaller wells. Of course, overall costs could increase due to the cost of the distribution system.

Managing land use to control septic tank pollution refers to the need to limit septic tank densities and to prohibit septic tanks in areas with inadequate soils. Land use plans could include such provisions. In some developing areas, it may be most economical to allow initial units to use septic tanks; but after population densities exceed some established limit, then centralized sewage treatment systems could be built. (See Chapter 8 on land use controls to manage ground water problems).

6.2.4 Improved Septic Tank Codes

A. Description

Revisions to current state and local codes governing the siting, installation, and maintenance of septic tank systems could include: (1) better criteria to ensure that septic tank-soil absorption systems are allowed only where soil conditions, geology, aquifer characteristics, and topography are suitable; (2) improved design and installation specifications and on-site inspection; and (3) provisions for regular inspections and maintenance, including reporting the method of septage disposal (approved landfill or through a sewage treatment plant). Additional measures which might be included in the codes are requirements for multiple drainage fields for large systems and restrictions on septic tank densities (as discussed above).

Inadequacies in current regulations exist, for example, with regard to separation distance requirements between drainage fields and water wells. These were largely developed 50 years ago and are not based on a sound, scientific understanding of the subsurface environment. A major deficiency is the use of the percolation test which is often applied to determine the permeability of soil for the absorption field. The percolation test is considered to be a less accurate measure of soil suitability than infiltrative capacity of the soil. The high rate of variability of the percolation test, plus the fact that it is rarely performed by the standard method, raises questions as to its validity (Scalf, Dunlap, and Kreissl 1977; Wilmington-New Hanover Planning Dept. 1980; Canter, Knox, and Kamat 1983).

B. Current Status

State regulations, which are usually enforced at the county level, typically include the following elements: drainage field design and standards for minimum lot size, ground slope, percolation rate, soil characteristics, and depth to the ground water. Some states also require a detailed plan of septic tank design, equipment specification, and separation distances from drinking water wells, surface springs, property boundaries, and building foundations. They may also require fill of abandoned septic tanks and inspection by state or local officials. Periodic maintenance to pump-out and dispose of septage is recommended every three to five years, depending on the size of the tank, but it is not mandatory (U.S. EPA 1977). The diversity of existing state codes regarding minimum setback distances for absorption fields is a further indication of the lack of knowledge about the transport and fate of pollutants in the subsurface environment (Scalf, Dunlap, and Kreissl 1977).

North Carolina has revised its method of determining site suitability by conducting lot by lot on-site inspections based upon four groups of parameters: (1) topography; (2) soil characteristics; (3) ground water elevation; and (4) depth to bedrock. The Wilmington-New Hanover Planning Department in North Carolina uses a system of soil classification as a major factor in determining the suitability of an area for septic tank systems. Soils are divided into four clases, with classes I and II suitable for septic systems and classes III and IV unsuitable (see Section 3.2). Maine has completely revised its state codes in an effort to make the regulations more applicable to local problems (U.S. EPA 1977). The U.S. EPA (1980a) in its design manual for on-site disposal systems establishes criteria for siting trench and bed systems and separation distances but these are recommended criteria, not mandatory standards.

C. Advantages

The trend in migration to suburban and rural areas is expected to continue, not only in the Southeast, but for the nation as a whole. Many of these nonurban areas are too sparsely populated to make construction of central sewer systems economically feasible (Troyan and Norris 1977; Hagedorn, McCoy, and Rahe 1981) and this increases the reliance on individual on-site disposal systems.

Revision of existing codes would allow state and local governments to put into practice improved procedures to minimize the increased threat of ground water pollution resulting from this growth in septic tank usage. This policy option is technically feasible and allows flexibility to account for site specific conditions. It is also attractive from the administrative viewpoint as it involves no radical change in the regulatory system, but rather just a revision of the existing codes to reflect the current state-of-the-art technology.

D. Disadvantages

Increased costs and inadequacies in scientific information are two possible disadvantages of this option. Higher costs could be incurred for developing new regulations, implementing new methods of testing site suitability, and enforcing the codes. A technique has been developed to measure hydraulic conductivity (permeability) in the unsaturated zone but it takes longer to perform than the percolation test and involves the use of trained technicians conducting on-site tests (Canter, Knox, and Kamat 1983). To require field testing of both the saturated and unsaturated zones would be very costly. Mandatory maintenance and regular inspection would be an added strain on state and local governments in terms of cost and manpower. However, a licensing system for inspectors or state inspectors could be used with a procedure to certify or issue an operating permit (Yoder 1982). Increased permit fees could possibly pay for these increased costs.

The other disadvantage may be lack of information. Further studies are needed to assess the survival time of microorganisms in soil and ground water, particularly viruses; and the transport and fate of both inorganic and organic chemicals in the soil and ground water media. This information would help in developing realistic codes and regulations based on scientific information (Scalf, Dunlap, and Kreissl 1977; U.S. EPA 1980a). It might be premature to develop new regulations without further research into subsurface characteristics and the behavior of microorganisms and chemicals in the soil and ground water media.

E. Feasibility

Improvements made in septic tank regulations in North Carolina and other states suggest this option is feasible in the Southeast. Nevertheless, there are concerns regarding implementation of this option. The suburban/semi-rural developer and landowner are often very powerful and this option would result in limitations on density and possible prohibition of some developments if soil conditions are not suitable for septic tanks. One mechanism to minimize widespread objections might be to define priority problem areas where more stringent regulation and enforcement are most needed (Yoder 1982).

6.3 RUNOFF CONTROL OPTIONS

As discussed in Chapter 4, runoff from urban, suburban, and agricultural lands causes localized ground water problems in the Southeast. Runoff from these areas often contains high concentrations of suspended solids, nutrients, oxygen demanding materials, and pesticides. In addition urban and suburban runoff frequently contains heavy metals, hydrocarbons, and pathogenic and toxic materials. In some instances the first hour's runoff from a storm causes more urban pollution load than an equivalent period of raw sanitary sewage (Kubal 1981).

In this section agricultural runoff controls are briefly identified, followed by a more detailed description of urban and suburban runoff control options.

6.3.1 Agricultural Controls

Ground water pollution from agriculture can be reduced through farming and range management practices. These "Best Management Practices" (BMPs) were developed through the U.S. Environmental Protection Agency (1978) in conjunction with the U.S. Department of Agriculture to reduce pollution while maintaining or improving farm output. Many of the BMPs focus on soil erosion and stream sedimentation, although some also address pollution from fertilizers and pesticides. For example, rotating crops that require little or no nitrogen fertilizer, such as legumes, with other crops can substantially reduce the long-term average quantity of nitrogen leached from the soils. As another example, growing alfalfa or other deep-rooted crops that use the nitrates from deep zones reduces the movement of nitrogen into ground or surface waters and lowers surface application requirements for nutrients.

As with nutrients, BMPs for pesticides aim at reducing the amount applied and control the timing, type, and method of application.[1] These control practices can also be used in conjunction with integrated pest management (IPM). IPM combines traditional pest control methods, such as crop rotation, with more sophisticated measures, such as computer analysis of an insect's life cycle. The balance between pests and their predators can be determined, and pest outbreaks can be estimated. Outbreaks may then be managed by a combination of chemical, biological, and mechanical controls that are typically site specific (Novoltny and Chesters 1981).

---

[1] In Florida, pesticide management is regulated by the Pesticide Application Law, which requires user training and certification. The farmer or commercial applicator must be retested and recertified after four years. A fine of up to $1,000 is charged for noncompliance (Austin 1982).

BMPs are also directed at controlling runoff of oxygen demanding substances and pathogens. For example, BMPs for feedlots include: building of roofed confinements; manure storage areas; land application of wastes; diversion channels and holding ponds; and monitoring to detect ground water pollution.

BMPs are now largely implemented through voluntary programs and, in general, these voluntary programs have few incentives. Additional incentives could include cost sharing, tax credits, and government subsidies. Cost sharing can encourage participation beyond what may be attempted using only the resources of individual farmers. In the Southeast, states generally have had some cost-sharing programs through the Agricultural Stabilization and Conservation Service. For some approved projects this agency provides federal funding of 50 to 80 percent of the total cost for implementing BMPs while the local conservation district (i.e., county) may provide the balance.

Currently, direct costs incurred in installing BMPs are business expenses and are legitimate deductions in determining taxable income. South Carolina, however, also provides a tax credit for equipment purchased for certain BMP tillage practices. However, these tax incentives do not provide sufficient motivation to encourage widespread use of BMPs.

Mandatory programs that would require use of specific BMPs are apparently viewed in the Southeast as unnecessary, expensive, and difficult to enforce. However, mandatory pollution prevention measures may be appropriate to reduce ground water pollution in high use or aquifer recharge areas.

6.3.2 Urban and Suburban Runoff Controls

A. Description

Policies for reducing urban and suburban runoff as a source of ground water pollution include technical design and maintenance activities implemented primarily at the local level. These technical options include: improving drainage and storm water handling systems; improving municipal cleaning and maintenance programs; improving vegetation cover; instituting land use controls; and requiring private sector design and maintenance standards for commercial activities.

Drainage and stormwater handling options include: (1) separate stormwater drainage systems isolated from the sewer system; (2) stormwater drainage combined with the sewer system; (3) partly separate drainage where, for example, roof water flows into the sewer systems and street runoff is drained naturally or into a stormwater drainage system (Imhoff, Miller, and Thistlethewayte 1971); (4) above-ground drainage in open ditches; and (5) utilization of existing natural above-ground flow patterns. Any of these drainage systems can be equipped with screening devices, such as in-line filters, trash traps, or screening. These systems may also drain to several types of holding and/or disposal systems such as retention areas, waste-water treatment plants, underground percolation systems, disposal wells, or streams and other surface water bodies. Retention ponds may provide only for evaporation and percolation of runoff, or they may be utilized for preliminary treatment, such as removal of solids. Retention areas vary from man--made ponds with treatment facilities to natural wetlands, such as marshes. A still uncommon method of holding runoff temporarily is known as "blue-green development," where tennis courts or other suitable facilities serve as small impoundments during storms (Kaiser, et al. 1973).

Vegetative cover is sometimes referred to as an aid to removing excess nutrients and other pollutants from runoff before it percolates into ground water. Vegetation approaches may be particularly applicable to the Southeast where marshes are relatively common and could be used in runoff management. Vegetative cover can retard overland water movement, thus allowing suspended solids to settle out of the water column and permitting water to gradually infiltrate the surface soils and underlying rock formations (Metropolitan Dade County Planning Dept. 1979).

Land use and subdivision controls are available to local and state governments in several forms and are used to help maintain the quality of different aspects of the natural environment. Where ground water quality is concerned, local regulations concentrate on drainage systems, runoff treatment, and maximization of permeable land surfaces. Development density, open space, and maximum lot coverage regulations are aimed toward maximizing permeable surfaces and minimizing runoff (see Chapter 8 on Land Use Management).

B. Current Status

Various methods of handling stormwater are in use alone or in combination in a variety of southeastern locations, though it is unknown how widespread use of each method is in the Southeast. Stormwater drainage systems have been designed primarily to reduce flood danger and to protect surface water quality; little attention has been paid to drainage systems as they relate to ground water management. Four locations in the Southeast (Myrtle Beach, South Carolina; Tampa, Florida; Winston-Salem, North Carolina; and Knoxville, Tennessee) have runoff control programs initiated by EPA as part of the Nationwide Urban Runoff Program to develop prototype control projects (Tuller 1982).

Stormwater drainage systems are often provided in cities. Combined stormwater/sewer drainage is found in Atlanta, Chattanooga, Louisville and other cities (Hill 1983). However, these cities have inadequate capacity to treat the combined flows during many rainfall events. Retention/detention ponds are "one of the most prevalent mechanisms of stormwater runoff control" (Kubal 1981). As an example of the retention/detention pond approach in Region 4, plans for control of runoff at Orlando International Airport include a drainage system leading to detention ponds equipped with baffles for the removal of floating solids and hydrocarbon pollutants. Runoff is then to be routed to a large pond for long-term retention, evaporation, or percolation into the surface aquifer. The airport has also planned for the use of marshes as part of a retention system (King 1981). Golf course and park ponds "often serve also as areas where stormwater runoff can be held and released slowly" (Texas Water Resources 1982).

Drainage wells are used extensively in some parts of the Southeast. In Orange County, Florida, there are more than 400 drainage wells, mostly into the upper Floridan Aquifer (Kubal 1981). As the upper Floridan is still an important supplier of potable water in Orange County, disposal of untreated runoff could endanger this water source. In areas of limestone, such as Florida and other coastal plain areas, sinkholes also tend to behave as a runoff drainage mechanism.

Municipal maintenance such as street sweeping/vacuuming is utilized in some cities to help clear impervious surfaces of materials that could be picked up by, and degrade the quality of, runoff. Regenerative air or vacuum-type sweepers have been recommended by the South Florida Water Management District (1982). Maintenance activities to clean retention ponds and disposal wells are also important and may be a neglected element of city cleaning programs.

Vegetative cover has received some attention in the Southeast as a means for controlling runoff. Ordinances for landscaping and tree protection have been suggested as a part of runoff control, and such ordinances are in effect for Myrtle Beach, South Carolina (Schwartz 1980). Part of the purpose of the Tree Ordinance for Leon County, Florida, is to protect trees to help control flooding and erosion (Thurow, Toner, and Erley 1975). The marshes in the retention system of Orlando International Airport are used in part because of the cleansing value of plants. The South Florida Water

Management District (1982) suggests the use of emergent plants in drainage systems to help absorb the nutrients carried by runoff.

Land use and subdivision regulations to control stormwater runoff are in effect in some southeastern localities. A Dekalb County, Georgia, ordinance regulates alterations of land and topography, the removal of vegetation, and specifies drainage system measures along with other erosion and runoff control measures. The subdivision regulations of the City of Tallahassee and Leon County, Florida, regulate stormwater management, requiring drainage systems to include features to minimize pollutants in runoff and requiring treatment or retention facilities. The Aquifer Recharge Ordinance of Volusia County, Florida, requires permits for any development in the Potential Recharge Area (areas of greatest potential aquifer recharge) in the county, including the building of any permanent structures (Thurow, Toner, and Erley 1975).

C. Advantages and Disadvantages[1]

If levels of treatment can be maintained with stormwater flows, combined runoff with sewage has the advantage of potentially treating runoff to the same level as sewage, and a higher quality water might be attained. Treated water may be percolated after treatment to replenish ground water. If treated to a high quality level, runoff can be "recycled" as is treated sewage, decreasing dependence on primary water sources. Combined sewer overflows and storm sewer discharges are subject to NPDES permits, and treated runoff must meet applicable NPDES requirements for discharge (U.S. EPA, Office of Research and Development 1980). Combined systems would, of course, lead to larger wastewater treatment plants. A high cost of treatment and cost for maintaining peaking capacity would occur.

In most cases, however, combined stormwater/sewer systems have insufficient capacity for rainfall and result in the discharge of raw sewage (Hill 1983). Since much of the Southeast tends to receive rainfall in intense cloudbursts and stormfronts, provision of sufficient wastewater peaking capacity can be difficult and expensive. Due to this problem, attention is often directed at isolating runoff, rather than combining and treating it, even though it contains high levels of contaminants.

---

[1] Information from the Nationwide Urban Runoff Program (NURP) prototype projects may prove valuable for evaluating appropriate runoff handling options. Twenty-eight urban areas have been selected for inclusion in NURP, which was instituted by EPA to gather data for the assessment of urban nonpoint source problems and their effects on receiving water quality. Most of the NURP prototype projects were to have been completed between FY81 and FY83 (Council on Environmental Quality 1980; U.S. EPA, Office of Water Program Operations 1981), but due to project delays only about one-third of the projects have been completed by 1982 (Tuller 1982).

Retention ponds on permeable substrates can help renew ground water supply. The ponds may also provide immediate storage of runoff to be treated later. However, retention ponds require space which may not be available. Without runoff treatment, percolation from ponds could cause ground water contamination in some circumstances. One study found that "up to 90 percent of the suspended solids in the entering stormwater" may settle to the bottom of the pond (Texas Water Resources Institute 1982). A Florida study found that stormwater runoff into a lake "can contain relatively high concentrations of chloride, copper, total lead, and nutrients as well as high values of chemical oxygen demand and alkalinity," and that accumulation of lead in lake sediments occurs (South Florida Water Management District 1980). Besides possible percolation to ground water, the accumulation of such materials in publicly accessible ponds may be a hazard to public health if used for wading or swimming. If sediments accumulate, periodic dredging may be required. Retention areas may also provide habitat for pests such as mosquitoes.

Well disposal can provide a means to recharge ground water, and if runoff is treated prior to disposal, potable water sources may be replenished. If runoff is not treated, disposal into nonpotable sources can be accomplished rapidly.

Street sweeping provides removal of many solids before they are picked up by stormwater, and may provide an aesthetic service as well. As ground water pollutants may be attached to the materials removed, street sweeping may be quite helpful. Negatively, though, street sweeping is a conspicuous consumer of fuel, and efficiency for improved runoff quality may be questionable.

Vegetation provides natural filtering of runoff, and is often aesthetically pleasing. Vegetation can remove nutrients and other pollutants and can enhance percolation into soils due to slowed water movement. However, large areas of vegetation may be required to make improvements in water quality--an impracticality in urban areas. An increase in nutrients could speed up vegetative succession in some areas or, conversely, runoff could contain pollutants or an overabundance of nutrients harmful to plants. Plants may also be unable to absorb some chemicals at a rate sufficient to protect ground water.

Land use and subdivision controls may be especially appropriate to protect critical aquifer recharge areas. They may be designed in conjunction with purposes other than runoff control and ground water quality maintenance. Land use controls can avoid construction and equipment costs. Disadvantages of using land use controls for the protection of ground water include public resistance and legal questions (see Chapter 8). Administrative requirements can be high, and the possibility of corruption also exists.

D. Feasibility

In some localities certain options may meet with political resistance or with problems of adaptation to local conditions. Most of the options discussed represent the installation of new equipment or additional maintenance activities. Political opposition for these options will be based primarily on a desire to control municipal budget outlays. The adoption of combined runoff/sewage treatment with adequate capacity, for example, would present a high cost relative to other options. Existing systems that handle drainage of stormwater are simply large conduits to the nearest waterway, blocked by small diversion weirs to intercept dry-weather flow (Hill 1983). Providing additional treatment would be difficult, expensive, and time-consuming, in an economic environment where many municipalities may have inadequate treatment for dry-weather flow. However, in some systems increased storage can be found in deep tunnels and vaults, or in sewer mains which may be almost empty or underutilized. Park and golf course ponds and "bluegreen development", for example, could be adapted for use as retention basins, particularly in residential areas if owners can be convinced of the benefits.

Recharge, drainage, and disposal wells are feasible in some areas of the Southeast, as illustrated by their extensive use in Florida. The major constraint on this method of runoff disposal is the possible contamination of potable ground waters. Managers may avoid this option unless some level of predisposal treatment is provided.

Street sweeping is currently utilized in cities across the U.S. and incurs no feasibility problem as long as municipal budgets are adequate. In some of the economically less-well-off communities of the Southeast, however, their cost could meet with some objections due to inconspicuous ground water benefits.

Vegetative cover can be relatively easily utilized in an urban runoff handling program and much of the Southeast has naturally lush vegetation. The major difficulties with this option are the provision of adequate open space in urban areas and possible public resistance to any type of "tree ordinance" or landscaping regulation necessary to make the option effective.

In some localities land use controls may be constrained by traditional southern resistance to such regulation. Zoning regulation proposals, for instance, continue to meet resistance in parts of the Carolinas. However, land use controls have met with some success in southern Florida.

6.4 ENERGY AND MINERAL PRODUCTION

Chapter 4 described ground water quality problems and issues associated with energy and mineral production; especially important in the Southeast are coal and phosphate mining and oil and gas production. Ground water concerns include:

- Large land areas impacted by coal mining in Tennessee, Kentucky, and Alabama and the potential for ground water degradation, especially from acid mine drainage;
- The lack of attention given to potential ground water impacts from noncoal mining;
- Possible deficiencies in regulations governing oil and gas drilling to prevent ground water pollution;
- The existing and potential ground water pollution caused by past practices of leaving unplugged abandoned wells and exploratory boreholes; and
- The lack of monitoring and research activities aimed at improving the understanding of ground water pollution from these activities.

Table 6-1 identifies two policy options (out of many possible ones) to deal with these problems: (1) improved management for noncoal mining; and (2) improved controls for oil and gas production. The first is discussed only briefly, while the second is treated in more detail.

6.4.1 Noncoal Mining Controls

As discussed in Chapter 4, the Federal Surface Mine Control and Reclamation Act (SMCRA) and associated state programs include measures for mitigating ground water effects of coal mining. However, similar programs do not generally exist for noncoal mining; improved management for noncoal mining is intended to address this deficiency. One way this policy option could be implemented is to extend the requirements of SMCRA for ground water impact mitigation to other noncoal minerals. In fact this possibility was envisioned in the Act; Section 709 called for a study to assess the applicability of the requirements of the Act to noncoal minerals. This study has been completed by a committee of the National Academy of Sciences (National Research Council 1979). While the findings from this study suggest it would not be appropriate for an across-the-board extension of the Act to noncoal minerals, they do not specifically address the advantages and disadvantages of applying just the ground water protection measures to noncoal minerals. Nevertheless, given the diversity of the types of mining activities and their potential ground water impacts, the problems could be addressed less comprehensively at the state level. Each state could survey the types of mining activities and their potential for ground water degradation and then develop programs that require mine operators to implement mitigation measures and monitoring. At present, states usually rely on general water pollution control statutes to protect water resources from noncoal mining. Phosphate mining in Florida and in North Caroilna are two examples of where states have focused specific attention the ground water impacts of noncoal mining.

6.4.2 Improved Controls in the Petroleum Industry

A. Description

As described in Chapter 4, petroleum exploration and development occurs in many southeastern states, especially Mississippi, Alabama, Kentucky, and Florida. Although levels of development are not comparable to states such as Louisiana, Oklahoma, and Texas, onshore oil and gas development poses some risks to ground water resources in the Southeast. The options discussed in this section primarily deal with technical performance for dealing with well drilling and mud pit related risks. The Underground Injection Control Program (UIC), identified in Chapter 4 deals with brine disposal wells of the petroleum industry.

There are three major oil field activities that produce risk to ground water: brine disposal, drilling fluids use, and enhanced oil recovery (Fairchild, Hall, and Canter 1981). Brine disposal problems ensue from abandoned brine disposal ponds, brine injection well leakage, and abandoned wells. Drilling fluids have some potential for pollution when drilling activities penetrate a fresh water aquifer. Enhanced oil recovery operation may pollute ground water if spills, injection well failure, or seepage through fractures occur (Knox and Canter 1980). However, most industry practices and regulatory agencies minimize these risks. Southeastern states without a long history of petroleum development may have a special difficulty in attempting to manage potential problems (Yoder 1982).

To protect potable ground water resources from oil and gas drilling and production, one approach is a regulatory program which (1) specifies design and performance standards used for well drilling and off-site brine disposal; (2) provides adequate means for enforcement; and (3) provides a means for cleaning up aquifers which are accidentally polluted (e.g., pollution bonds).

The technical and performance standards should cover the following elements: (1) casing above and below fresh aquifers; (2) controls on the types of drilling muds used, especially when drilling through fresh aquifers; (3) regulations on brine disposal procedures, including manifest systems to protect against illegal dumping; and (4) well abandonment procedures and reporting requirements. Many of these technical areas are covered by the UIC program (see Chapter 4).

Mechanisms to ensure adequate enforcement should consider two items. Most importantly, adequate financial and manpower resources must exist in the regulatory agency for inspection, monitoring, and record keeping. Secondly, from a ground water quality perspective, regulatory authority could be centralized in an environmental agency, rather than in state oil and gas boards or commissions.[1]

Despite the adequacy of the standards and enforcement capability, the potential will always exist for ground water contamination, either from accidents or from bad practices on the part of some drilling contractors. Thus, financial provisions to pay for the clean-up of pollution incidents that do occur should also be a key part of the regulatory program.

In most cases, such regulatory programs probably should be developed and enforced at the state level. However, an exception to this may be in areas where oil and gas drilling operations threaten critical municipal water supply sources. In such cases, local governments may wish to develop their own regulatory programs since they will have the most direct interest in protecting their water supply sources. Whether developed at the state or local level, the program should be made stringent enough to provide real protection, while also allowing the flexibility to account for varying conditions. For example, not all ground water resources or strata have the same value and thus do not necessarily deserve the same degree of protection (see Section 6.6 on "classification" systems).

B. Current Status

All states with oil and gas production have laws for protecting ground water from oil and gas activities. Given the increased attention over the past few years to the need for ground water protection, each of the states in the Southeast has established a review of its laws and regulations for oil and gas activities and for implementation of the UIC program. However, Kentucky and Tennessee have indicated they do not intend to seek UIC program primacy (Chapter 4). States, regional areas, and local governments could analyze their regulations relative to codes which are considered to be effective for protecting ground water. For example, the Texas law is often identified as one of the better ones. Also, the Association of Central Oklahoma Governments (ACOG) has developed a "suggested code" for local governments which draw water from the Garber-Wellington aquifer in Central Oklahoma (ACOG 1982).[1] Ordinances based on this model code have been adopted by several municipalities in Central Oklahoma and are being considered by most others. This geographic area is characterized by a very critical relationship between ground water and oil and gas. The total population is around a half million and ground water from the Garber-Wellington aquifer supplies much of the municipal water--over 300 municipal wells are currently active. At the same time, over 15,000 oil and gas wells have been drilled in the area.

---

[1] Both oil and gas development regulatory programs, including controls to prevent ground water pollution, and the UIC program are administered through oil and gas commissions in many states.

Because of the magnitude of the potential problems, the ACOG code can be considered relatively stringent. No areas in the Southeast currently face problems of similar magnitude. Nevertheless, this suggested code could serve as a basis for identifying possible areas of improvement in state programs and as a beginning point for local governments in the Southeast whose ground water supplies may be threatened by oil and gas drilling and production.

Despite the general adequacy of state laws and regulations as identified above, there is also general agreement that the laws and regulations are not adequately enforced. For example a 1977 study found:

> "The primary cause for concern is not dearth of regulations but lack of enforcement...In most instances, less than strict enforcement is a result of limited funds and manpower available to the regulatory agency. Also, because the oil and gas industry is usually treated as a separate entity which has its own regulatory group, more than one agency is faced with related ground water problems. This overlap makes coordination difficult...." (U.S. EPA, Office of Water Supply 1977, 319).

Therefore, a key existing issue to be addressed in reviewing state and/or local government regulatory programs is enforcement. In the case of the ACOG approach, this problem has been addressed by municipalities requiring, for each oil and gas well drilled, a permit fee, which goes into an enforcement fund. A well permit fee had always existed, but often it went into general municipal funds; not only was this probably illegal[2] but also adequate funds for enforcement were not being appropriated by the local governmental units. The problem of agency coordination might be reduced by transferring enforcement from state oil and gas boards to the appropriate environmental agencies who deal with other ground water protection programs.

---

[1] This work by ACOG is a direct result of a study of the Garber-Wellington Aquifer mandated by Congress and administered by the U.S. EPA.

[2] The oil and gas industry in central Oklahoma was in the process of filing legal challenges to this practice (Wallace 1982).

Finally, state and/or local governments could include in their reviews of existing regulatory programs, provisions to finance clean-up in the event of ground water contamination. In the case of the ACOG code, this is addressed by a municipal requirement that a pollution bond be posted.

C. Advantages and Disadvantages

The objective of this option is increased protection given to ground water resources. As described above, it addresses the major limitations of existing approaches, especially enforcement and accountability.

Possible disadvantages relate to (1) possible delays and/or increased costs on the part of drillers and producers in order to comply with the regulations, and (2) increased government expenditures required to enforce the regulations. While some increased costs ae probably inevitable and necessary, the basic issue is one of balancing these increased costs with the value of the ground water resources being protected. The trade-off point will vary from location to location, and thus the regulations need to be implemented flexibly. For example, the level of the pollution bond required should be determined by the value of the ground water resource being protected. In central Oklahoma, ACOG suggested this bond be set at $1 million, although the amount implemented by municipalities in the area varies. In areas where ground water is not a crucial water supply source, the bond could be set at a much lower amount.

The regulations should be implemented in such a way as to minimize unnecessary delay; for example, by specifying minimum time requirements for the regulatory agency to either approve or disapprove permits. Drilling contractors' fees are often based on a daily rig cost ($4,000-$7,000 per day have been common depending on the depth capability of the rig and conditions in the industry [Petzet 1982]) and thus any regulatory delays incurred after drilling has commenced can be quite costly.

In the case of central Oklahoma, ACOG has estimated that their regulations add about $15,000 to the cost of a well (Wallace 1982). The increased governmental regulatory costs are largely paid for out of the permit fees which are included in this $15,000 figure. For typical wells in the area which may cost from $500,000 to $2.5 million to drill, this represents a cost increase of between 0.6 and 3 percent.

D. Feasibility

Clearly some resistance to this option can be expected from the oil and gas industry over concern that the regulations would increase the costs of oil and gas exploration and development and place obstacles to timely development. The best way to approach this problem may be to establish a committee consisting of representatives of all parties-at-interest, including oil and gas industry, to review and make recommendations on needed changes. For example, in the development of the ACOG code, the oil and gas industry (represented by the Oklahoma Independent Petroleum Association) worked closely with the ACOG staff and others in developing the suggested code.

6.5 HAZARDOUS WASTE MANAGEMENT FACILITY CONTROLS

As discussed in chapters 3 and 4, hazardous wastes pose a threat to ground water from substandard disposal facilities, improper transport and handling, and a shortage of approved commercial facilities. A critical issue is enforcement at all levels of government of the Resources Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response and Liability Act (Superfund or CERCLA). If long interim periods and lax enforcement are adopted or if legislative authority expires without reauthorization, ground water quality is likely to suffer.[1]

Concerns over the danger associated with hazardous wastes have resulted in strong local opposition to new disposal sites (Yang 1981). This opposition has led to diminishing numbers of approved disposal sites, particularly landfills. This in turn contributes to the transport of hazardous waste over long distances. In addition, operations continue at existing facilities that are substandard in terms of current guidelines identified in RCRA.[2] These conditions have contributed to the rise of prices for treatment and disposal of hazardous wastes, which in turn exacerbates problems of illegal dumping particularly from small generators or companies which cannot afford such prices.

The first two options in this section address problems with small generators: (1) provide a collection system for small generators of hazardous waste; and (2) establish a manifest system for small generators of hazardous waste. The last two options address the difficulties of establishing new hazardous waste disposal facilities: (1) a decentralized or local siting authority; and (2) a centralized or state authority for siting.

---

[1] CERCLA (Superfund) legislation is authorized through 1985.

[2] See 40 CFR 122, 260, 264, and 265 for a description of standards applicable to owners and operators of hazardous waste treatment, storage, and disposal facilities. Federal Register, July 26, 1982: 32274-23388.

6.5.1 Local Hazardous Waste Collection and Storage Services

A. Description

RCRA recordkeeping does not apply to generators of less than one ton/month of hazardous waste. This limit was deemed necessary given the large number of such generators and the necessity that RCRA's enforcement be manageable.[1] However, this exclusion threatens ground water because small generators may dispose of their hazardous waste in an environmentally unsafe manner. Disposal of these wastes in municipal sewers, landfills, and along the roadside has been mentioned by state authorities. Small generators in many instances cannot afford the cost of disposal charged by the hazardous waste collection and disposal industry. The latter sometimes has to charge even higher prices when the quantities of hazardous waste are small.

Given the adverse public health, environmental, and economic impacts that may result from the unsafe disposal of hazardous waste, one option is for local authorities to provide a collection and storage service for hazardous waste produced by small generators prior to its transport, treatment, and/or disposal by the hazardous waste management industry. Such service would exclude generators covered by RCRA and be limited to collection and temporary storage. Small generators would cover all or part of the cost of this service.

B. Current Status

Municipal governments are already engaged in hazardous waste collection. Most cities operate disposal services for transformer fluids (PCB's), solvents, pesticides, and other materials used in city-operated activities. These services are typically provided only for government agencies, however. Radioactive waste from state facilities may also be collected by a central state agency. Following initial collection activities for both hazardous and radioactive waste, transport and disposal is handled through a commercial operator. Examples of such municipal collection and storage services for hazardous wastes accessible to the private sector do not exist, with the exception of emergency fire department or police department assistance with flammable or explosive materials.

---

[1] In response to the small generator "loophole" HR 6307 was introduced in the 96th Congress to reauthorize RCRA. This bill narrowed the small generator exemption from 1,000 kilograms (2,200 pounds) to generators of less than 100 kilograms (220 lbs) a month. HR 6307 did not pass.

C. Advantages and Disadvantages

The major advantage would be a reduction of illegal disposal of hazardous waste in municipal sewers, landfills, roadsides, and streams. This should minimize public health and environmental hazards associated with improper practices. Considerable reduction in the cost of cleaning up polluted sites should also be achieved.

The cost of establishing and operating this service is the major disadvantage. Any public sector costs may be reduced by the participation of small generators. The cost will also differ among urban/industrialized and rural/nonindustrialized areas.

D. Feasibility

Public opposition may be expected if such a program will require increased levels of taxation. In addition, large hazardous waste generators covered by RCRA may object to subsidized municipal collection unless they are also served by it.

6.5.2 Local or State Manifest System

A. Description

Currently, small generators can operate outside the manifest system unless they use the services of the hazardous waste management industry for transport, treatment, and disposal. Only by using the services of disposal brokers is the manifest obligatory to small generators. There is also little information on the quantity and quality of hazardous waste from small producers; that is, the numbers, identity, location, means of transport and treatment, and final disposal of these wastes are poorly known. To overcome these problems, local government, in cooperation with state government, may establish a requirement to extend the manifest system for transport and disposal of hazardous waste to cover small generators.

B. Current Status

Most states of the Southeast have carried out limited surveys of hazardous waste generators (both large and small). These surveys, together with generic EPA studies on hazardous waste produced by industrial sectors, can serve as starting points for more detailed surveys of small generators. The risks associated with the lack of information on hazardous waste produced by small generators have been acknowledged by most state authorities responsible for hazardous waste management in the Southeast. However, there is no requirement in operation at the local or state level for extending the manifest system to small generators.

C. Advantages and Disadvantages

Local and state agencies could acquire systematic information on the generation, treatment, and disposal of hazardous waste produced by small generators. Such information can serve as the basis for establishing manifest system requirements. This should discourage small generators from resorting to illegal or environmentally hazardous methods of disposal.

The geographic proximity of local government agencies to small generators may enhance compliance and monitoring; however, because transport/disposal usually crosses local government boundaries, state involvement to maintain a centralized register is required. The economic cost born by local authorities (and probably the state) together with the paperwork faced by the small generators are the principle disadvantages to any type of manifest system.

D. Feasibility

Local authorities will have the task to establish the programs and assign the department and personnel which will have to run the manifest system. Cooperation with state authorities may prove necessary if this reporting system is to be enforced effectively. Participation of state government to meet part of the cost of the program will also facilitate its adoption. The strongest objections to adoption will likely be from the small generators themselves because of manpower requirements and cost. Also, in the past, industry has objected to disclosures of process inputs or wastes on the grounds that proprietary information is revealed. RCRA, for example, provides a basis for industry objection to listing hazardous waste and such recourse may be sought through the courts (Marnell 1981).

6.5.3 Increased Local Government Role

A. Description

Ground water pollution and potential for adverse health effects have created a climate in which the siting of new hazardous waste management facilities is strongly opposed. The passage of RCRA left wide responsibilities and authority for the management of hazardous waste with the states (see Section 4.3). However, this authority has been of limited usefulness because the acceptance or rejection of a hazardous waste management facility may be due to such factors as proximity of hazards and perceived economic benefits (employment, income) which are felt primarily by the local community (Yang 1981). However advantageous the geologic and geographic conditions, a hazardous waste management facility may be opposed unless economic and social advantages are perceived by the community to outweigh the risks.

Local authorities can affect the siting and use of hazardous waste management facilities through zoning ordinances and by taxes, such as property taxes or service fees. Land use planning and zoning can be used to provide a buffer area between the facility and populated areas, to identify sites which are least objectionable to the community, and to require the necessary infrastructure such as roads and railway tracks.

A hazardous waste land disposal facility does not offer substantial employment or investment to improve the local tax base. This is particulary so if the facility is only planned for disposal. Several options are available to local officials to increase the economic benefits of accepting a hazardous waste management facility. They may increase investment and thus the tax base by encouraging or requiring the facility to include other disposal techniques, such as incineration, chemical treatment, and recycling and resource recovery, as well as analytical and research laboratories (Mosher 1982). They may also require, for example, that operators transport hazardous waste by trucks that are registered locally. Local taxes or fees could also be imposed on incoming hazardous waste. Clearly the cost/benefit balance of accepting a hazardous waste management facility can be improved and local authorities can be instrumental for achieving this objective.

B. Current Status

Several southeastern states have established mechanisms affecting the distribution of benefits to local governments. Mississippi, for example, has enacted legislation giving local authorities 75 percent of the income from taxation on incoming hazardous waste for disposal. Mississippi also provides low interest loans for building the infrastructures which are necessary to support a hazardous waste management facility (see Section 4.2). Although this program was not initiated by local governments, it does encourage local governments to take a more active role in the siting process. Alabama has passed similar legislation for the county that has jurisdiction over the major hazardous waste facility owned by the Chemical Waste Management Company.

C. Advantages and Disadvantages

Local authorities have an understanding of community values and attitudes and may have a demonstrated ability for administering zoning ordinances and fee assessment programs; this is especially the case in larger municipalities and counties. By providing a local basis for siting decisions and the means for substantial economic benefits, local authorities may reduce the private suits and nuisance claims characteristic of public objections to the hazardous waste industry (Gulick 1981).

On the other hand, some counties do not currently have zoning ordinances and thus have no experience in their administration. In addition, local authorities may lack the technical expertise needed to effectively regulate a developing hazardous waste management industry.

D. Feasibility

There are likely to be divided opinions on having local governments play an increased role in the siting of hazardous waste management facilities. Environmental interests may perceive such responsibility as being more subject to local corruption and they might also doubt that local authorities could provide adequate regulatory expertise. In addition, some may view the attempts to provide increased economic benefits as simply a means to "buy-off" the local populace at the cost of increased health risks. Nevertheless, overall it apppears that at least some aspects of increased local responsibility are politically feasible in the Southeast, as is evidenced by statutes in Mississippi and Alabama.

6.5.4 Centralized State Authority

A. Description

Despite a wide spectrum of hazardous waste management regulations, state government is generally constrained in siting new hazardous waste management facilities due to conflicting, fragmented, and overlapping agency responsibilities and due to restrictions imposed by local authorities. This limitation applies even in those few states of the Southeast where the state has the authority to overrule local zoning ordinances. When preemptive authority has been exercised, opposition has developed leading to challenges of state authority in the courts and reversals of state-level decisions (Yang 1981).

For states to become more effective in siting hazardous waste management facilities, institutions could be developed to accomodate conflicting priorities among state and local agencies. Such arrangements could include the establishment of a state committee for siting hazardous waste management facilities which includes representatives of state and local government, industrial and commercial interests, and technical and economic specialists. This committee could be given as much authority as state traditions and legislation allow in the selection of disposal sites and operational requirements, and could develop recommendations to improve the distribution of costs and benefits among those affected by hazardous waste management facilities.

B. Current Status

Tennessee established a hazardous waste siting board, consisting of persons with technical expertise in agriculture, geology, and engineering; representatives from generating industries, environmental and local interest groups; and ex-officio members from the departments of Public Health, State Planning, and Economic and Community Development. The board mandate includes the development of a hazardous waste management plan for the state, but its responsibility is limited to off-site facilities. Georgia and Alabama have considered establishing similar boards. North Carolina has had a Governor's Task Force on Waste Management to develop a hazardous waste facility siting policy, but the authority of this task force was limited to providing policy recommendations (North Carolina Legislative Research Commission 1981). California, which is characterized by a shortage of disposal sites, has a program to ban landfill disposal of the most hazardous chemicals and has a task force to site new hazardous waste facilities that use advanced disposal techniques (Mosher 1982).

C. Advantages and Disadvantages

Increased responsibility of the state through the establishment of a committee (or board) may facilitate the cooperation between state and local authorities in an area where both are major stakeholders. This may allow for political, technical and social issues to be resolved in a manner that accomodates diverse interests. A hazardous waste siting board may also serve to enhance communication in a typically fragmented state management program (North Carolina Legislative Research Commission 1981). In addition, a state level board may be most effective for considering long term and state-wide environmental and economic issues related to siting of hazardous waste management facilities.

However, increased responsibility of the state in siting hazardous waste management facilities also has disadvantages in potentially intensifying conflicts with local governments which traditionally have authority over local zoning. In addition, a state committee or board may find it difficult to implement its decisions. Compromise made at the committee level may be politically unacceptable at the state or local level unless significant enforcement and implementation authority is provided.

D. Feasibility

The feasibility of implementing this option will depend very much on the degree of authority given to the state level committee or board. On the one hand, if the board is established by the governor to serve only as a planning and/or advisory body, then feasibility is high as demonstrated by such actions in several southeastern states. On the other hand, forming a new body at the interface of two established levels of government is not an easy task. It will have to take some authority from both levels, and its decisions will have to be enforced by these two levels of government. Its establishment, and its success, will depend (a) on the need for increasing the capacity of hazardous waste management facilities to avoid adverse environmental and public health hazards and (b) on the selection of the institutions participating in the committee and the ability of the persons representing them to cooperate and compromise.

6.5.5 Summary

Table 6-2 summarizes the characteristics of the four policy options discussed for dealing with hazardous waste management issues as they relate to ground water protection. Certainly, many other policy options exist but these four deal with two of the key problems identified in Chapter 4--the exclusion of small generators from RCRA manifest requirements and the difficulty of siting new commercial hazardous waste management facilities. The four options are not mutually exclusive; in fact, all four could be implemented simultaneously.

The first three options all give local governments a much more active role in managing hazardous wastes. There are advantages to this approach generally in terms of locating the governmental role close to the sources of hazardous wastes. Nevertheless, it is also clear that such policies would not be effective without being implemented in all or most counties, and for this to happpen it will require some form of state action. The fourth option aims at more centralized planning and/or controls. This has certain attractive features but such policies are likely to be difficult to implement if they attempt to preempt existing decision-making authority at the local level.

TABLE 6-2: SUMMARY: HAZARDOUS WASTE MANAGEMENT FACILITY CONTROLS

Option	Description	Current Status	Advantages	Disadvantages	Feasibility
Hazardous waste manifest system by local government to cover small generators.	Local authorities establish manifest system which covers generation, transport, treatment, and disposal of hazardous waste produced by small generators. Would probably require state-wide coordination.	Not adopted by any state.	Information on generation, transport, and disposal of hazardous waste from small generators will be acquired. Reduced potential for illegal or improper hazardous waste disposal.	Economic cost for local authority to establish the required programs, hire personnel, etc. Local authority may lack necessary technical expertise. Will be ineffective unless manifest system coordinated at state level.	State governments and EPA may consider sharing some of the costs with local authority which decides to establish such a program.
Collection and storage system at local level for small generators.	Local authorities provide collection and storage services to small generators of hazardous waste excluded from RCRA; transport and disposal costs paid by small generators.	State and local governments provide collection and storage services for their own operations but they are not extended to the private sector.	Reduced potential for illegal disposal of hazardous waste. System useful when hazardous waste management facilities are distant.	Cost to local authorities to establish and run such a service.	If covered (partly or wholly) by local taxation, possible objection from large hazardous waste generators. Likely opposition by citizens if costs are subsidized by government.
Increased local government roles in siting.	Extend zoning and taxing authority to siting and the taxation of hazardous waste management facilities.	Some counties and most municipalities have zoning authority.	Provides for local evaluation and method for affecting distribution of benefits.	Limited expertise of some local governments.	Implementation strictly by actions of local governments likely to be difficult. State initiated programs have been implemented in Mississippi and Alabama.
Increased state government roles in siting.	Provide planning and/or control for facility siting to a state board.	Tennessee has established a planning and advisory board; Georgia and Alabama have considered such an option.	May enhance prospects of obtaining suitable sites. Provides a forum to resolve conflicting interests.	Increased government costs. Potential conflict of interests with existing state and local agencies.	Feasibility will depend critically on degree of authority given to the board.

6.6 STANDARDS FOR GROUND WATER QUALITY MANAGEMENT

Strategies for ground water quality management can include (1) standards established to control directly the characteristics of discharges to the environment, or (2) standards based on environmental characteristics and uses. A wide range of specific options can be included in these two broad categories. For example, controls over discharges can take the form of establishing numerical concentration limits on pollutants in the effluent or they can require certain types of effluent treatment technology based on the type of industry.

Policies that protect ground water based on environmental characteristics and ambient water quality can take the form of: (1) nondegradation standards; (2) uniform statewide ambient quality standards; or (3) a system of classifying aquifers to maintain different levels of quality or use. Specific policy options may also involve a combination of discharge controls and measures that recognize ambient ground water quality criteria. The first four options in this section (see Table 6-1) are described only briefly while aquifer classification is discussed in more detail in Section 6.6.5.

6.6.1 Effluent Standards to Protect Ground Water

Effluent standards for discharges affecting ground water would regulate materials discharged to the environment that at some point may contaminate ground water. These effluent standards could be based either on required treatment technologies or on numerical limits on the quantity and/or concentration of pollutants. Ground water discharge controls would differ from surface water discharge controls of the National Pollution Discharge Elimination System (NPDES) as the former generally apply to all liquid, semisolid, and soluble wastes not discharged directly to streams, such as landfills, surface impoundments, spray irrigation, subsurface leaching beds, and other discharges or applications of material onto or into the ground (Goad 1982, Trele 1982).

Developing technology or "design-specification" standards is an intensive regulatory activity (Pennsylvania 1979). For example, the existing NPDES regulatory effort for discharges to "navigable" receiving streams as applied to industrial or municipal wastewater treatment systems requires the use of appropriate technology based standards such as "best practicable control technology currently available" and "best available technology economically achievable" (see Clean Water Act as amended 1977). These design standards are based on elaborate and continuing technology review. Although some states, such as Pennsylvania, protect ground water with design standards, the approach is often criticized because of the wide variation of environmental circumstance and the engineering expertise required by regulatory agencies for implementation (Goad 1982, Trele 1982).

Effluent standards based on numerical concentration limits and/or the volume discharged, known as performance standards, offers an alternative approach that provides discharges with more flexibility. Like design standards, however, performance standards need to be based on scientific assessments to determine the risk posed by specific levels of discharge for each type of pollutant. In the case of ground water, establishing a uniform scientific basis of assimilative capacity of the environment is difficult because of the wide variation in soil characteristic and local geohydrology. Because of these wide variations New Mexico, for example, has rejected regulatory approaches to maintain ground water quality based on the quality of effluent to a receiving pond or land application (Goad 1982). Partly for these reasons many regulatory agencies continue to approve percolation ponds, lagoons, drain tile fields, and land applications of wastewater on an individual application basis. Nevertheless, discharge controls to "nonnavigable" areas might be based on generalized performance criteria where standards are relatively clear, such as prohibitions on nonbiodegradable toxics.

6.6.2 Permits for Ground Water Discharges

A permit program to approve discharges potentially affecting ground water is one basis for implementing a ground water protection program. Such a permit program places restrictions on discharges based upon criteria described above, such as design or performance based effluent standards. Alternatively, discharge permits could be based on desired or existing characteristics of the water table or aquifer. In practice state discharge permits can make use of a combination of these regulatory approaches.

New Jersey, for example, regulates all discharges, storage areas, or activities which may impact ground water (Trele 1982). New Jersey's permits require use of appropriate technologies as well as meeting ambient standards of nondegradation or antidegradation (see below) depending on aquifer characteristics and use. New Jersey's permit system includes the following provisions: (1) a permit application 180 days prior to discharge; (2) an environmental impact statement; (3) a public review process; (4) monthly to quarterly monitoring to protect the designated uses of the state's aquifers; and (5) is self supporting on applicant fees (Trele 1982).

New Mexico's discharge permit (or discharge plan) process contrasts with New Jersey's in emphasizing the maintenance of specified ambient water quality standards (see Section 6.6.4). New Mexico's discharge controls require that ambient standards not be violated (Goad 1982); thus although discharge permits are required, this approach is essentially a protection stategy based on ambient quality rather than discharge characteristics.

6.6.3 Nondegradation Strategy

One method of developing water standards is to utilize the existing natural quality levels of a given site. Dischargers would not be allowed to introduce materials that would result in a reduction of quality from this natural level. New Jersey and Virginia have adopted this nondegradation policy for some aquifers (Trele 1982; Magnuson 1983). Monthly or quarterly monitoring is required in New Jersey for discharges to assure that degradation does not occur. Nondegradation policies are generally criticized on the basis that ambient concentrations represent arbitrary standards not based on the protection of health or welfare and may require unjustified economic costs. In addition, by not allowing preferential protection of high quality aquifers through controlled degradation of others, nondegradation may place drinking water supplies at increased risk (Magnuson 1983).

6.6.4 Ambient Numerical Standards

Antidegradation (or limited degradation) strategies set numeric concentration limits for pollutants to provide a basis for economic development while protecting specific water uses. New Mexico, for example, has established a policy that essentially uses the national drinking water standards as ambient ground water quality standards for all waters less than 10,000 ppm TDS. New Mexico has modified and extended these national standards, and now has standards for 35 chemical groups (Goad 1982). If natural or existing quality is worse than these standards, the existing quality becomes the standard which allows no further degradation. New Mexico officials believe their approach is easily monitored, provides adequate protection, and does not depend on burdensome discharge design or performance standards (Goad 1982).

6.6.5 Aquifer Classification

A. Description

Aquifer classification provides several types of quality standards or degrees of management for different ground water resource areas. Classification systems can be used to differentiate priority ground water areas for high levels of protection from areas that are least environmentally sensitive and more suitable, for example, as sites for waste disposal facilities (U.S. EPA 1980b).

EPA "model" classification guidelines, proposed in 1980, suggested that states consider current or projected future uses of the aquifer as an important criterion for classification, recognizing that aquifers vary greatly in yield and quality (U.S. EPA 1980b). There could be as many as seven "use" categories or classes:

- Highly valuable drinking water (sole source or pristine);
- Drinking water with minimal treatment;
- Drinking water with extensive treatment;
- Agricultural uses (irrigation, livestock);
- Industrial uses (cooling, process water);
- Mining and energy development; and
- Limited waste disposal.

Further important considerations in developing classes would be aquifer yield, natural quality of the ground water, vulnerability to pollution and alternative sources of water in the area (Pye and Kelley 1982). The EPA model proposed three levels of management based on the classification: (1) the most stringent regulations for protection of water that is highly valuable to human use or ecological function; (2) less stringent standards that would provide limited siting opportunities of facilities dealing with hazardous and toxic wastes while ensuring ground water quality suitable for drinking (the majority of fresh ground water would apparently be found in this class); and (3) technical requirements for facilities involved with hazardous and toxic wastes that would require strict monitoring to ensure the protection of public health (Pye and Kelley 1982).

Thus, classification approaches recognize various criteria to be considered for the management of different geographic areas or aquifer zones. Classification systems contrast with other management approaches that uniformly protect ground water such as statewide nondegradation strategies. Classification systems attempt to use hydrogeologic, engineering, and use criteria for establishing classes that have direct management applications. Specific management requirements, such as protection standards for aquifers used as potable water sources are typically an inherent part of the classification system.

States may develop a program to classify in advance all aquifers for subsequent approval and management of water wells or disposal activities. Alternatively, class designations may be applied during the approval process for wells or disposal facilities. The latter approach reduces the administrative burden of classifying all of a state's complex hydrogeological resources, but provides little advance planning guidance to managers or developers. Some communities and states may also engage in de facto classification since they tend to give attention to or protect recharge and drinking water areas more than brine aquifers, for example (Tripp 1982).

B. Current Status

At least eleven states or territories (Table 6-3) have developed varying classification systems (Pye and Kelley 1982; Fisher 1982): (1) classification based primarily on type of aquifer use and quality; and (2) classification based on sensitivity to pollution. New Mexico has a two-class system based on the total dissolved solids contents of the water. Connecticut, New Jersey, New York, North Carolina, and Wyoming have considerably more complex systems that recognize demands by multiple interests with varying requirements for quality. South Carolina is reviewing state classification systems and is looking at state systems such as New York's as a possible approach (Duncan 1982).

Florida has recently adopted a three class system as follows:

(1) Class G-I: all ground waters in single source aquifers having a TDS content of less than 10,000 mg/l.

(2) Class G-II: all ground waters obtained from other than single source aquifers with a TDS content of less than 10,000 mg/l.

(3) Class G-III: all ground water with a TDS content greater than 10,000 mg/l. Discharges into these waters will be considered on a case-by-case basis to ensure against danger to the public health, safety, and welfare.

Criteria have been drafted for any discharge into classes G-I and G-II aquifers so that established water quality standards may not be exceeded unless the background value for a particular criterion is greater than a stated maximum. These same criteria may not necessarily apply to the less restrictive G-III class if there is "no danger to health, safety, or welfare of the public" (Pye and Kelley 1982).

North Carolina's ground water classification system emphasizes potential use and existing ground water quality (North Carolina Administration Code, Title 15, Chapter 2). Regulations for classifying ground water and protection of classified waters were adopted in June 1979. The North Carolina ground water classification system establishes six classes as shown on Table 6-4. The first two groups represent potable water found in depths below 20 feet, although GA is less saline than GSA. The second two groups represent water table ground water in the shallow saturated zone where a recycling and pollution removal function is recognized by the state. This water is also potable. However, class GA is

TABLE 6-3: EXAMPLES OF CLASSIFICATION CRITERIA

State	Number of Classes	Selected Class Criteria
Connecticut[a]	(4)	Drinking water; degree of treatment; and use for disposal
Guam	(5)	Not known
Florida[b]	(3)	TDS content; others
Maryland	(3)	Aquifer characteristics
New Jersey	(4)	TDS content; special ecosystems; others
New Mexico	(2)	TDS; others
New York[c]	(3)	Drinking use; chloride level; others
North Carolina[d]	(6)	Depth; drinking use; and chloride concentrations
Vermont	(2)	
Virginia	(4)	ph; nitrite; others
Wyoming[e]	(6)	Domestic use; livestock use; fish and aquatic use; industrial use; and location

Source: Based on description in Pye and Kelley 1982; Magnuson 1982, 1983.

[a] Adopted September 1980.

[b] Adopted 1981.

[c] Adopted September 1978.

[d] Adopted June 1977.

[e] Adopted August 1980.

TABLE 6-4: SUMMARY OF NORTH CAROLINA GROUND WATER CLASSIFICATIONS AND STANDARDS

Class	Major Usage	Location (Subsurface Depth)	Example of Standard Not to be Exceeded
1. GA	Potable water supply	Soil depths below 20 ft.	Below 250 mg/l chloride; TDS below 1000 mg/l and other restrictions
2. GSA	Potable mineral water	Soil depths below 20 ft.	Above 250 mg/l chloride but not to exceed 100 percent of naturally occurring concentrations
3. GB	Source of recharge and a recycling zone to remove pollutants. Also a source of potable water.	In the shallow saturated zone to depth of 20 ft. below the land surface	Deleterious substances allowed but not to contravene established drinking water standards
4. GSB	Source of recharge to saline surface and ground water. Also potable mineral water	In saturated zone to depth of 20 ft. below surface	(as above)
5. GC	Water supply other than drinking, culinary, or food processing	Any depth	Concentrations of deleterious substances not to exceed those at time of classification
6. RS	Restricted	Any depth	Toxics in excess maximum allowable concentrations

Source: Adopted from descriptions in North Carolina Administrative Code 1979.

recharged from fresh ground waters (less than 250 mg/l) and GSB is recharged from saline ground waters. The fifth classification recognizes that some waters, while not potable, are useful for other purposes. The sixth class, restricted, contains toxic or deleterious substances in excess of maximum allowable concentrations (North Carolina Administration Code, Title 15, June 1979). Actual classification of specific aquifers is currently underway on a county-by-county schedule. Although the waters are being classified, administration arrangements and an enforcement program to assure their protection or restoration have not been approved by the legislature.

The above state classification system contrasts to a local aquifer management program proposed by New Hanover County, North Carolina, in May 1982 (New Hanover County Planning Department, 1982). The emphasis in the New Hanover County program is to protect recharge areas and aquifers sensitive to contamination, rather than to protect use categories or existing quality. Six categories of land areas are included: (1) primary recharge area of principal aquifer (confined and artesian); (2) secondary recharge area of principal aquifer (under water table conditions); (3) recharge area of water table; (4) discharge areas for ground water flow; (5) poor aquifers or areas not recharge zones; and (6) shallow water table sands. The designations are used potentially to implement landfill, septic tank, and land use controls to protect recharge areas. For example, the unconfined sections that recharge a primary aquifer (Class 2 above) are most sensitive to pollution from surface activity (New Hanover County Planning Dept. 1982) and would receive priority attention.

C. Advantages

The principle advantages of the classification systems are the establishment of management priorities and provision for site-specific differences in environmental protection and economic growth. The flexibility of classification can be viewed as highly desirable since enforcement resources are always limited. Statewide advanced classification offers advantages for initiating long-term ground water protection plans.

In areas of intensive aquifer use, applying use and quality criteria for classification may provide greater short-term management efficiency than does applying criteria for protecting sensitive areas. On the other hand, protecting sensitive recharge areas may assure better protection over the longer term. The advantages appear highly dependent on local circumstances and implementation. For example, if few sensitive or critical areas were identified, administration problems might be reduced even though aquifers were intensively used and contained water with a high quality.

D. Disadvantages

All classification systems require a solid information base and a technically competent administrative system. A detailed mapping process, if selected as an implementation strategy, may also be technically difficult to achieve (Magnuson 1982). However, technical precision may not be essential to achieve some degree of management (Tripp 1982). If implementation results in restricting surface liquid and solid waste disposal, these approaches could also lead to a reduction in economic growth in some areas. If classification systems also attempt to protect areas for potential future uses they run into technical difficulties in predicting future use trends (Howells 1981).

Classification systems also may commit some aquifers in low quality classes to a near permanent contaminated status. Unlike surface water classification, future changes in use or quality may be difficult or impossible to accomodate, because ground water takes decades or centuries to recover. Finally, classification based on few criteria, such as the use criterion alone, has the potential disadvantage of directing management resources to areas that could have low or minimum risk of contamination.

E. Feasibility

There appear to be some barriers or obstacles to adopting classification options. For example, class designations that recognize or permit ground water degradation are often opposed by landowners and residents in those areas (Magnuson 1982). As a result, for example, Connecticut has apparently designated too few areas for waste disposal, arousing the opposition of those needing disposal sites.

The classification systems all require technical information on use, quality, and hydrogeology. They would all require state technical expertise and a substantial data development program to assign the class categories to particular aquifers. This commitment to government infrastructure may not be politically acceptable to some states. States such as North Carolina, however, are apparently progressing in their classification efforts.

If states classify theatened aquifers on an ad hoc basis, or classify areas or groups of aquifers broadly, technical precision may not be needed to achieve a feasible management strategy (Tripp 1982).

6.7 AQUIFER REHABILITATION OPTIONS

The previous policy options discussed in this chapter aim at preventing ground water pollution. Yet, many aquifers have already been polluted and will continue to be polluted despite efforts to reduce the threat. The purpose of this section is to briefly review technical alternatives available for rehabilitating a polluted aquifer. In addition to the rehabilitation measures, abandonment is also an alternative that sacrifices the aquifer and requires developing a new source of water. Abandonment is widespread, for example, in water table aquifers in proximity to landfills. Abandonment of hazardous waste sites is intended to be minimized through authorization of rehabilitation funds provided through the Comprehensive Environmental Response and Liability Act of 1980 (Superfund or CERCLA).

6.7.1 Description

Abatement, clean-up, and restoration are all options for rehabilitating polluted aquifers. Abatement options include those measures that lead to the cessation of pollutants moving into the ground water and the elimination of the movement of pollutants having already reached the ground water either by physical (e.g., slurry walls) or chemical means. Cleanup requires removing the polluted ground water and treating it on the surface or removing the pollutant in-situ by chemical or biological methods. Restoration measures attempt to return the aquifer to its natural state. This will most often include a clean-up measure plus natural or artificial recharge. Stopping the polluting activity is, of course, the first step for any rehabilitation option.

Abatement techniques include the following:

(1) Subsurface barriers are a means of stopping the lateral migration of polluted ground water by placement of an impermeable wall or barrier. The three most common means are slurry walls, grout cutoffs, and steel sheet piles. Each technology involves sinking a continuous, impermeable wall deep enough to tie into an underlying impermeable formation, thus effectively closing all avenues of exit for the polluted ground water. It should be noted that impermeable barriers are rarely used alone; they usually require a complementary technology such as removal wells.

(2) Interceptor systems are most often in the form of interceptor trenches (also referred to as French drains or infiltration galleries) placed around a polluted formation to capture the polluted ground water as it moves laterally. The most common application of this technology has been to capture floating hydrocarbons from relatively shallow ground water formations.

(3) Well systems are the most popular means of abating ground water pollution. Typically, a well system can be classified under one of three headings: modification of pumping; pressure ridges; or pressure troughs. Modification of pumping could involve decreasing pumping rates or pumping from deeper formations or any other modification of the existing pumping procedure. Pressure ridges involve placing a series of injection wells around a site and injecting fresh water through these wells to restrict pollutant movement. This technology has found its widest application in coastal areas to prevent salt water intrusion. Pressure troughs (purge wells) are the most popular method for abating polluted ground water movement. By placing a series of removal wells at judiciously selected sites and pumping at prescribed rates, the polluted water can be removed before it moves away from the site.

Cleanup strategies usually take one of two forms. They can be either removal systems or in-situ systems. Removal systems are the most common type of cleanup measure and involve removing the polluted water through purge wells or interceptor systems and treating the water by physical or chemical methods. The in-situ technologies involve either chemical or biological stabilization of the polluted ground water within the aquifer. In-situ chemical stabilization involves injection of various chemicals to precipitate the pollutant out of solution and trap it in the soil matrix. In-situ biological stabilization involves injection of nutrients and oxygen and allowing the naturally occurring soil microorganisms to biologically degrade the pollutants in the ground water.

Restoration strategies are measures that attempt to return the aquifer to its natural state. These measures usually involve removal of the polluted ground water and some sort of subsequent recharge. Recharge can be allowed to proceed naturally or can be induced artificially. Artificial recharge can be achieved through use of injection wells or by infiltration from recharge ponds or basins.

The above options are certainly not discrete and will involve overlap. For instance, all rehabilitation strategies involve some clean-up measures. Also, any truly effective cleanup strategy will include some abatement and prevention steps; obviously, one would not attempt to clean-up a polluted aquifer without also identifying and removing or treating the source of the pollution.

The choice of any ground water rehabilitation activity will be heavily influenced by site-specific characteristics. Some of the technologies are not applicable to certain pollutant types that bind closely to subsurface soils. The feasibility of a number of the technologies will be a function of the aquifer characteristics, and both clean-up and restoration may be impossible to achieve.

6.7.2 Current Status

The current status of abatement measures to reduce pollutant movement is not well known. A few specific applications of procedures to reduce pollutant movement can be found in the literature (Neely, et al. 1981). However, because ground water pollution control measures are often used in response to some sort of legal action, there appears to be an unwillingness to disclose information about these measures.

Removal and treatment of polluted ground water is widely practiced in the Southeast and some examples can be found in Neely, et al. (1981). The in-situ technologies have been applied in the industrial Northeast. The status of restoration strategies in the Southeast is unknown, although several sites have been cleaned up in South Carolina, for example (Duncan 1982).

Examples where no rehabilitation occurs can be found at landfills, waste disposal sites, or other activity that has caused subsurface pollution. Superfund action is pending for some of these sites, while others have no proposed action. For example, the Flemington Landfill that was once the major landfill for Wilmington, North Carolina has polluted nearby wells (see Chapter 3), yet no action is forthcoming (North Carolina. Dept. of Natural Resources and Community Development 1978).

6.7.3 Advantages and Disadvantages

Abatement measures tend to be less costly than cleanup or restoration. The technologies involved in abatement are more advanced, although their application to ground water pollution has only been very recent. One disadvantage of some abatement measures is their permanent nature (for example a slurry wall). Both the quality of construction and the effectiveness of some subsurface barriers are difficult to monitor. Finally, abatement measures in most cases are not designed to remove the pollutant. This fact and the permanent nature of some measures represent an irretrievable commitment of the ground water resource.

The main advantage of clean-up measures over using abatement measures above is that they do attempt to remove the pollutant. However, this is usually offset by increased costs. Some of the in-situ technologies are also technically unproven.

Restoration strategies are attractive in that they attempt to return the aquifer to its original state. However, restoration strategies tend to be both more costly and more time consuming than the other strategies.

Experience with rehabilitating aquifers is very limited, hence reliable data on costs are scarce. Some cases of cleanup of polluted ground water in New Jersey have been made available by the National Center for Ground Water Research and are briefly reviewed in Table 6-5 to give an indication of costs. For these cases, most of the costs were incurred by companies which were responsible for both the pollution and the cleanup.

The New Jersey experiences indicate that cleanup measures cost between $100,000 to $300,000 for the first year, including capital and operating costs. (Estimates of operating costs past the first year were not available). However, large scale cleaning efforts can be much more expensive. The estimate for cleaning up a dump located in sandy soils that received 800,000 gallons of heavy metal and hydrocarbon hazardous waste (in New Hampshire) is approximately 1 million dollars per year (Weston 1982). An abandoned metals mine in Oklahoma that contaminated an aquifer with lead, zinc, and other metals is estimated to cost between $500,000 to $900,000 per year up to 20 years (1981 dollars) (Knox, Stover, and Kincannon 1982). Clearly aquifer rehabilitation efforts are costly undertakings and need to be carefully evaluated against both potential for successful cleanup and the costs of developing alternative sources of water.

6.7.4 Feasibility

The feasibility of implementing abatement, clean-up, or restoration measures is constrained by both political, economic, and technical factors. First, rehabilitation is costly and sources or funds are limited. Waste management facility operators are frequently unwilling or unable to provide adequate funds, and "Superfund" sources are limited. Second, some of the measures are still technically unproven, particularly the in-situ technologies. Third, some of the technologies might be constrained by existing legislation; for example, the injection of certain chemicals for cleanup could be restricted by the UIC program. Fourth, the technical feasibility of rehabilitation strategies will depend on favorable geologic conditions and restoration may be highly dependent on adequate quantities of recharge.

6.8 SUMMARY AND CONCLUSIONS

Regulation of individual sources of pollution, ground water quality standards, and aquifer rehabilitation represent three components of a ground water protection strategy discussed in this chapter. Aquifer rehabilitation, however, is both a costly and uncertain approach. It appears unlikely that aquifer rehabilitation can substitute for a strong pollution prevention effort. However, aquifer rehabilitation is necessary for existing contamination cases and future cases that will no doubt occur. Also, rehabilitation may be useful in conjunction with timely monitoring

TABLE 6-5: EXAMPLES OF CLEANUP COSTS FOR POLLUTED AQUIFERS IN NEW JERSEY

Pollutant	Remedial Action	Cost[a]
Mainly trichloroethane (TCE)	Air stripping with recharge of aquifer via infiltration ponds. Purifying at about 100 gallons per minute (gpm). Feed from 250-1,000 parts per billion (ppb) of TCE, reduced to less than 10 ppb.	$300,000 (capital cost and one year operating costs).
Chloroform, carbon tetrachloride	Removal of polluted ground water by pumping through affected well at 350 gpm and disposing into storm sewer. Second interception well to be drilled after twelve months.	$250,000 for capital cost and one year operating costs.
Organic chemicals	Twelve wells drilled in overburden formation and eight for bedrock monitoring. The ground water withdrawn was used for cooling and treated with other process effluents with activated carbon before discharge into surface water.	$200,000 per year (including capital cost).
Trichloroethane (TCE)	Interceptor trench and disposal into storm sewer. Disposal of contaminated sediments from ponds and trench excavation.	$100,000
Acetone, methylene chloride, butyl alcohol	Injection-recovery trench system with biostimulation treatment. COD of feed reduced by 80% in effluent. Decontaminated water reinjected into aquifer via trenches.	$150,000 (includes capital cost and operating costs for three months).

Source: Knox, R. C. University of Oklahoma, National Center for Ground Water Research, 1982.

[a] Costs approximate, as of September 1981.

information (see Chapter 8) to provide a capability for responding rapidly to contamination events. If a more rapid response approach were possible, effectiveness could be improved and costs might be reduced. However, it should be recognized that many factors can create delay in the abatement and cleanup process: polluters may deny responsibility and engage in drawn-out litigation, and federal and state pollution control agencies often engage in lengthy studies and prioritization reviews.

Pollution source control and a strategy to protect critical, sensitive, or high quality aquifers will provide the greatest degree of certainty for ground water quality protection. For much of the rural Southeast, options to minimize ground water contamination by septic tank pollution and agricultural runoff are important. Both of these pollution problems can be improved by implementation of existing engineering and agricultural practices, although further research would aid in designing more effective and less costly measures.

The options for improved energy and mineral production controls and hazardous waste facility controls can be directed towards the development of more responsive industry and government oversight. With the growth of surface mining and industrial activities involving hazardous materials, greater attention to protection of ground water is an important consideration for many areas throughout the Southeast.

The establishment of ground water quality standards and discharge permits probably represents the most active area in state policy development. Several states, notably New Mexico and New Jersey, have permitting authority directly related to ground water protection. These states have taken very different approaches based on different ground water quality standards: New Mexico has statewide standards and New Jersey has a more elaborate classification system, but both systems have discharge regulations that recognize the diversity of aquifer characteristics. Both of these approaches may be useful for southeastern states. Thus, controls of point source and nonpoint sources can be implemented with either a classification or uniform standards approach for defining ambient water quality objectives.

Protection strategies that are based on classifying aquifers for different levels of protection recognize the differences in hydrogeological characteristics, sensitivity to pollution, and existing and potential uses. A major drawback to aquifer classification is the dependence on large amounts of information and the potential controversy over designating some aquifers to a lower protection status. These disadvantages must be balanced against the administration advantages of developing priorities for managing the diverse aquifers within states of the Southeast.

REFERENCES

Association of Central Oklahoma Governments. 1982. "Suggested Oil and Gas Ordinance." Memorandum to Garber-Wellington Association members, January 25.

Austin, W. 1982. Personal communication, October 11.

Brown, L. A. 1979. "Planning For Non-Point Pollution Control in North Carolina." Journal of Soil Water Conservation 34 (1): 8-10.

Burmaster, D. E., and R. H. Harris. 1982. "Groundwater Contamination: An Emerging Threat." Technology Review 85 (July): 50-62.

Canter, L. W., R. C. Knox, and R. P. Kamat. 1983. "Evaluation of Septic Tank System Effects on Ground Water Quality: Draft Report." University of Oklahoma, National Center for Ground Water Research, Norman, OK, May.

Council on Environmental Quality. 1980. Environmental Quality 1980: Eleven th Annual Report. Washington, DC: Government Printing Office.

______. 1981. Contamination of Ground Water by Toxic Organic Chemicals. Washington, DC: Council on Environmental Quality, January.

Duncan, D. 1982. Staff, South Carolina Dept. of Health and Environmental Control. Personal communication, June.

Ellis, T. 1982. Personal communication, October 12.

Fairchild, D. M., B. J. Hall, and L. W. Canter. 1981. Prioritization of the Ground Water Pollution Potential of Oil and Gas Field Activities in the Garber-Wellington Area. NCGWR 81-4. Norman: University of Oklahoma, National Center for Ground Water Research.

Federal Register. 1982. 47 (July 26): 32274-388.

Fisher, Cheryl. 1982. "Designating Aquifer Protection Areas in Vermont." Prepared for presentation at the Sixth National Ground Water Quality Symposium, Atlanta, GA, September 22-24.

Goad, Maxine. 1982. "New Mexico's Experience in Setting and Using Ground Water Quality Standards." Paper presented at the Sixth National Ground Water Quality Symposium, Atlanta, GA, September 22-24.

Gulick, T. E.. 1981. "Superfund: Conscripting Industry Support for Environmental Cleanup." Ecology Law Quarterly 9:524-78.

Hagedorn, C., E. L. McCoy, and T. M. Rahe. 1981. "The Potential for Ground Water Contamination from Septic Effluents." Journal of Environmental Quality 10 (January/March): 1-8.

Herndon, A. 1982. Personal communication, October 12.

Hill, David W. 1983. Staff, Air and Water Ambient Monitoring Section, Region IV, U.S. Environmental Protection Agency. Personal communication, May.

Howells, David H. 1981. "Comments on a National Groundwater Protection Strategy." Ground Water 19: 466-68.

Imhoff, Karl, W. J. Miller, and D. K. B. Thistlethwayte. 1971. Disposal of Sewage and Other Water-Borne Wastes. Ann Arbor, MI: Ann Arbor Science.

Interstate Oil Compact Commission (IOCC). N.d. "Water Problems Associated with Oil Production in the United States." Oklahoma City, OK.

Josephson, Julian. 1980. "Groundwater Strategies." Environmental Science and Technology 14 (9): 1030-75.

Kaiser, Edward J., et al. 1973. Promoting Environmental Quality Through Urban Planning and Controls. Springfield, VA: National Technical Information Service.

King, Charles H. 1981. "The Orlando International Airport: A New Concept in Surface Water Management." In Proceedings: Storm Water Quality Control Seminar, November 4. Orlando, FL: Orlando Area Chamber of Commerce.

Knox, R. C. 1982. University of Oklahoma, National Center for Ground Water Research. Notes from the New Jersey Department of Environmental Protection.

Knox, R. C., and L. W. Canter. 1980. Effects of Oil and Gas Field Activities on Ground Water Quality. NCGWR 80-30. Norman: University of Oklahoma, National Center for Ground Water Research.

Knox, R. C., E. L. Stover, and D. F. Kincannon. 1982. "Examples of Aquifer Restoration." Prepared for presentation at the Ninth Annual Ground Water Management Districts Association Conference, Scottsdale, AZ, December 1-3.

Kubal, Jerry E. 1981. "Impacts of Storm Water on Ground Water Quality." In Proceedings: Storm Water Quality Control Seminar, November 4, 62-79. Orlando, FL: Orlando Area Chamber of Commerce.

Loehr, R. C., et al. 1979. Best Management Practices for Agriculture and Silviculture. Ann Arbor, MI: Ann Arbor Science.

Magnuson, Paula. 1982. "Identification and Classification of Aquifers." Prepared for presentation at the Sixth National Ground Water Quality Symposium, Atlanta, GA, September 22-24.

______. 1983. "The Uses of Different Kinds of Aquifers." Paper presented at the Workshop on Ground Water Resources and Contamination in the United States, Washington, DC, March 14-15.

Marnell, M. F. 1981. "EPA's Responsibilities Under RCRA: Administrative Law Issues." Ecology Law Quarterly 9:555-78.

Metropolitan Dade County Planning Department. 1979. Comprehensive Development Master Plan for Metropolitan Dade County. Miami, FL: Metropolitan Dade County Planning Department.

Moore, Gardner and Associates. N.d. On-Site Waste Water Treatment and Disposal Alternatives. Georgetown, SC: Waccamaw Regional Planning and Development Council.

Mosher, Lawrence. 1982. "Who's Afraid of Hazardous Waste Dumps? Not Us Says the Reagan Administration." National Journal 14 (March 29): 952-57.

National Research Council. 1979. Surface Mining of Non-Coal Minerals. Washington, DC: National Academy of Sciences.

Neely, D., et al. 1981. Remedial Actions at Hazardous Waste Sites, Survey and Case Studies. Cincinnati, OH: U.S. Environmental Protection Agency.

New Hanover County Planning Department. 1982. New Hanover County Aquifer Management Program. Wilmington, NC: New Hanover County Planning Department.

North Carolina Administrative Code. 1979. Classifications and Water Quality Standards Applicable to Groundwaters of North Carolina. Title 15, chapter 21, sections .0100 and .0200. Raleigh, NC: Environmental Management Commission.

North Carolina Department of Natural Resources and Community Development. 1978. Ground Water Conditions in the Flemington Area of New Hanover County with Emphasis on Effects of the Landfill. Environmental Management Division. Report of Investigation 16. Raleigh, NC: The Department.

North Carolina Legislative Research Commission. 1981. Management of Waste and Other Environmental Programs Report of the 1981 General Assembly of North Carolina. Raleigh, NC: Legislative Research Commission.

Novotny, V., and G. Chesters. 1981. Handbook of Nonpoint Pollution Sources and Management. New York: Van Nostrand Reinhold.

Otis, R. J. 1978. "An Alternative Public Waste Water Facility for a Small Rural Community: Small Scale Waste Management Project." University of Wisconsin, Madison.

Pennsylvania. 1979. "Proposal for the Development of Pennsylvania Ground Water Quality Standards" (revised draft). N.p., October.

Petzet, Gialan. 1982. "Cost Declines Aid Exploration Economics." Oil and Gas Journal 80 (August 16): 87-90.

Pye, Veronica, and Jocelyn Kelley. 1982. "Groundwater Contamination in the United States, Part I: The Occurrence, Sources, Severity and Public Health Effects of Contamination" (first draft). Academy of Natural Sciences, Environmental Assessment Council, Philadelphia, PA, May.

Scalf, M. R., W. J. Dunlap, and J. R. Kreissl. 1977. Environmental Effects of Septic Tank Systems. EPA-600/3-77-096. Ada, OK: U.S. Environmental Protection Agency.

Schwartz, Larry. 1980. "Urban Stormwater: Its Impact and Control on the Grand Strand." In Proceedings of the 13th Annual South Carolina Governor's Conference on Water Resources, May 8-9. Columbia, SC: South Carolina Water Resources Council.

Shogren, Richard T. 1983. Staff, Kentucky Department of Environmental Protection. Personal communication, March 30.

South Florida Water Management District. 1980. Effect of Urban Stormwater Runoff to a Man-Made Lake on Groundwater Quality. Technical Publication 80-4. West Palm Beach, FL: South Florida Water Management District.

South Florida Water Management District. 1982. Permitting Information Manual. Vol. 4, Management and Storage of Surface Waters. West Palm Beach, FL: South Florida Water Management District.

Texas Water Resources. 1982. "Holding the Stormwaters." 8 (July/ August): 1-3.

______. 1982. "Texas Law of Drainage." 8 (July/August): 4.

Thurow, Charles, William Toner, and Duncan Erley. 1975. *Performance Controls for Sensitive Lands: A Practical Guide for Local Administrators, Parts 1 and 2*. Chicago, IL: American Society of Planning Officials.

Towers, C. H. 1982. Personal communication, October 12.

Trele, John. 1982. "The New Jersey Ground Water Discharge Permit System." Paper presented at the Sixth National Ground Water Quality Symposium, Atlanta, GA, September 22-24.

Tripp, James. 1982. Personal communication, November.

Troyan, J. J., and D. P. Norris. 1977. "Cost Effectiveness of On-Site and Community Sewerage Alternatives." *Civil Engineering (ASCE)* 47 (December): 84-89.

Tuller, Stewart. 1982. U.S. Environmental Protection Agency, Water Planning Division. Personal communication, October 14.

U.S. Environmental Protection Agency. 1978. *Nonpoint Source Control Guidance, Agricultural Activities*. Washington, DC: Environmental Protection Agency.

______. 1980a. *Design Manual: On-site Wastewater Treatment and Disposal Systems*. EPA-625/1-80-012. Cincinnati, OH: U.S. Environmental Protection Agency.

______. 1980b. *Proposed Groundwater Protection Strategy*. Washington, DC: Environmental Protection Agency.

______. Office of Research and Development. 1980. *Environmental Outlook 1980*. Washington, DC: Government Printing Office.

______. Office of Water Program Operations. 1981. *Water Quality Management Five Year Strategy: FY82 Baseline*. Washington, DC: Environmental Protection Agency.

______. Office of Water Supply and Office of Solid Waste Management Programs. 1977. *The Report to Congress: Waste Disposal Practices and Their Effects on Ground Water*. Washington, DC: Environmental Protection Agency.

Wallace, Greg. 1982. Association of Central Oklahoma Governments. Personal communication.

The Weather Almanac. 1977. Edited by James A. Ruffner and Frank E. Bair. 2nd ed. Detroit, MI: Gale Research.

Weston, R.F. 1982. Sylvester Hazardous Waste Dump Site Containment and Cleanup Assessment (draft). Concord, NH: R. F. Weston Inc., January.

Wilmington-New Hanover Planning Department. 1980. Classification of Soils in New Hanover County for Septic Tank Suitability. Technical Report No. 9. Wilmington, NC: The Department.

Yang, Edward. 1981. Assessment of Problems Related to Siting Hazardous Waste Management Facilities: A Core Study of EPA Regions IV and VI (draft). Washington, DC: Environmental Law Institute.

Yoder, Doug. 1982. Metro-Dade County (Florida) Department of Environmental Resources Management. Personal communication, October 28.

CHAPTER 7

WATER AVAILABILITY MANAGEMENT OPTIONS

7.1 INTRODUCTION

Many factors can affect the water requirements of an area, including weather conditions, technological developments, social attitudes and habits, economic cycles, the rate of development, and population changes. Generally, water availability has not been viewed as a problem in the Southeast--rainfall is plentiful; lakes, rivers, and streams are abundant; and ground water resources are widespread. However, some areas are experiencing water supply problems, particularly along the Atlantic Coast and throughout a large portion of Florida. Although most of the problems in the Southeast are local in nature, they can be quite severe and are becoming more widespread.

The existence of a physical supply does not guarantee that sufficient water is always available for use. Natural or man-made pollution may degrade the quality of the water and limit the uses for which it is fit. Even if potential water supplies do exist, they may not be close to the areas of greatest demand. In some instances, during seasonal dry periods or extended droughts, the normally used sources might become so depleted that demand is greater than the available supplies.

Water supply problems are especially important given the water demands associated with growth in populaton, industry, and irrigated agriculture.

- By the year 2000, the population of the Southeast is expected to be approximately 46.6 million with a total daily water withdrawal for domestic use of five billion gallons per day (bgd) and consumption of 1.5 bgd (U.S. Bureau of Economic Analysis 1980; Shepherd et al. 1980);

- Due, in part, to the concentration and expected growth of water intensive industries in the Southeast--paper and allied products, chemicals, petroleum refining, and primary metals--water consumption by manufacturers is expected to increase by 321 percent to 3.2 bgd by 2000 (Shepherd et al. 1980);

- Florida has more irrigated acreage than all the other states east of the Mississippi River combined (Lewis

1980). Irrigated acreage in Georgia has increased from less than 10,000 acres in 1951 to more than 750,000 in 1979 (Treadway 1980). Of the 325 mgd used for irrigation, 130 mgd come from ground water with substantial increases possible in the future (Kundell 1978); and

- Overall, surface and ground water consumption is projected to more than double (from 5.5 to 12 bgd) in the Southeast between 1975 and 2000 (Shepherd et al. 1980).

Compared to surface water, ground water is more consistently available during dry periods and frequently is of higher quality. Consequently, the use of ground water has grown and substantial increases in demand are likely to be made on this resource for municipal supplies, industrial needs, and agricultural uses. Whether ground water resources can meet the demand depends on how the supply is managed.

Although ground water problems increasingly are being recognized as important concerns in many areas of the Southeast, the lack of adequate institutional arrangements is a constraint on the ability of most of the states to manage ground water resources and deal with the problems and issues associated with its use. The increased use and overpumping of ground water already has led to problems in many areas of the Southeast (see Chapter 5).

- Ground water quality degradation by salt and brackish water intrusion is a serious problem in many South Atlantic and Gulf Coast locations, including much of Florida's coastal area, the Savannah and Brunswick areas of Georgia, and Beaufort County, North Carolina;

- Lowered ground water levels, which result in increased pumping costs, are particularly a problem in the Savannah, Georgia and southeastern South Carolina area, northeast Mississippi and northwest Alabama, in the area around Georgetown, South Carolina, in Brunswick County, North Carolina, and in the Delta and coastal counties of Mississippi;

- Land subsidence is occurring in many areas of Georgia, including portions of the northwest, southwest, and Savannah area, in southern Alabama, southeastern South Carolina, and particularly in central and northern Florida;

- Some areas of the Southeast--for example, the Savannah, Georgia/southeast South Carolina area, southwest Georgia, and portions of Florida--are experiencing multiple impacts from ground water overdraft.

This chapter discusses policy options to: (1) apportion ground water resources among potential users, particularly during times of short supply; and (2) help ensure the continued provision of adequate supplies without the negative impacts associated with overpumping (Table 7-1). Section 7.2 discusses ground water allocation options, including modifications to existing water laws and the use of permitting systems as a specific regulatory alternative.

In order to ensure adequate supplies and to guard against shortages during drought or crisis conditions, various structural alternatives can be used to maintain or increase the existing water supply. Options to augment ground water supplies or to supplement or replace this source with other water supplies are presented in Section 7.3.

Reductions in the amount of water used also can help ensure the availability of adequate supplies. Section 7.4 discusses domestic, industrial, and agricultural conservation practices and public education about conservation as techniques to reduce demand. Water pricing alternatives and pump taxes can be used to provide economic incentives for cutting back on water requirements and also are discussed in this section.

TABLE 7-1: WATER AVAILABILITY OPTIONS

General Category	Options
Allocate ground water resources	Modifications to existing water laws Permitting systems
Provide adequate supply	Expanded use of surface water Well field development and management Desalination Subsurface storage and retrieval Artificial recharge
Manage demand	Conservation Pricing alternatives Pump taxes

7.2 WATER ALLOCATION OPTIONS

Traditionally state governments have had the major responsibility for water allocation policy. In most of the Southeast, water supplies have been plentiful enough for state governments to remain relatively passive, allowing individual users to resolve conflicts over water through negotiation or litigation. However, localized shortages and periodic droughts have highlighted some weaknesses in the states' legal and institutional frameworks for allocating water.

An overview of these systems and of some of the issues and problems they raise has been provided in Chapter 5. The following section briefly discusses possible modifications to laws for allocating water. This is followed by a discussion of permitting systems as a specific regulatory option for managing water allocations.

7.2.1 Modification of Water Law

In the southeastern states, common law doctrines and statutory permit systems are the primary mechanisms for allocating both surface and ground water. Yet the existing permitting systems in most of the southeastern states have failed to become active management tools in the absence of strong public support for state control over allocation of supplies. The central concerns for most southeastern states are to clarify state goals for managing water use, to develop the administrative framework for accomplishing those goals, and to choose the specific legal and regulatory options for allocating water supplies among both present and future uses.

Each state differs in the degree to which its water allocation framework has been stressed by emerging ground water availability problems and issues. Florida, for example, has experienced both severe floods and drought which provided the impetus for major changes in its water management framework in the late 1960s and early 1970s. In contrast, South Carolina, despite increasing ground water problems, has never had a court case over a ground water conflict and has made only minor modifications to its management framework (Stallworth 1982). Thus, while Florida has moved toward a conjunctive management approach to surface and ground water allocation (see Chapter 9) and is currently modifying its specific regulatory ground water management strategies, South Carolina is in the initial process of studying and evaluating the adequacy of its water allocation laws (South Carolina Water Law Review Commission 1982).

Both states are experiencing similar interstate allocation problems. South Carolina's low country is experiencing lowered ground water levels from withdrawals in the Hilton Head Island resort area and from industrial and municipal withdrawals in the Savannah, Georgia, area; northern Florida, and southwestern Georgia also share the affects of heavy agricultural withdrawals from a common aquifer. Further, all these states have confronted the difficulties associated with water transfers. Thus, states have both unique and common problems to solve in developing allocation options.

Usually criticized because of its failure to respond to or even to anticipate new problems, water law in the Southeast can nonetheless be commended for its respect of the property rights concept and lack of government involvement (Trelease 1974; Oeltjen and Fischer 1978). Thus, a key concern for states in the Southeast is to modify those aspects of their water law doctrines which are particularly restrictive, such as requiring use of water on riparian or overlying land, while strengthening those aspects, such as individual control, which are viewed as beneficial for the state as a whole. At least five common law doctrines affect allocation decisions in the southeastern United States. These are:

- Riparian doctrine--provides water rights to the owner of land bordered or crossed by a natural watercourse and considered part of a contiguous tract in contact with the water and part of the watershed. Each riparian owner has the right to make reasonable use of water, in relation to the needs of other riparian owners (Kundell 1980; Cox 1982).

- English Rule of Absolute Ownership--this ground water doctrine presumes, unless positive evidence of an underground stream is presented, that ground water is percolating through the soil and belongs to the owner of the land. Restrictions on use are almost nonexistent, thus owners establish rights by simple capture of the resource (Cox 1982).

- American Rule/reasonable use--a modification of the absolute ownership doctrine which limits the withdrawing landowner's use of ground water to a beneficial purpose on the overlying land. Interference with a neighbor's supply is permitted if the use is beneficial and reasonable (Maloney et al. 1968; Dewsnup and Jensen 1973).

- Correlative rights--a modification of the riparian reasonable use doctrine, based on the theory of proportionate sharing of ground water among landowners from a common supply, especially during times of scarcity. This doctrine provides rights which are equal in priority regardless of the time they were secured and which may be based on the portion of land owned over the common source (U.S. Water Resources Council 1981).

- Prior appropriation--rights to use surface or ground water are generally awarded for beneficial use with priority of rights established by the time of application to the state (first in time, first in right). Thus, in times of scarcity the first authorized user has priority over later appropriations (Putt 1981; U.S. Water Resources Council 1981).

Comprehensive permitting systems have also been established by statute in many states in order to facilitate the state's role in allocating water; this alternative is discussed in more detail later in this section. Other, less comprehensive approaches to establishing state involvement in allocation issues are discussed briefly in the following pages.

Many water problems in the South have stemmed from the fact that the existing doctrines do not assign sufficient property rights to create a framework or economic incentives for resource use or access. Directly related to this is the failure to clearly identify the available remedies for injured parties (Putt 1978).[1] Historically, water law in the Southeast has followed the philosophy that society's interests will be enhanced or maximized if individuals are free to make decisions about resource development according to their own economic self-interest. Thus, the law has served to define and protect rights to use water as private rights relatively secure from state interference. Riparian users of surface water have found their rights to be relatively secure because the courts have typically respected traditional uses and water supplies have been abundant. The absolute ownership and reasonable use doctrines applied to ground water have permitted landowners to use their ground water in unlimited amouts for traditional land development activities regardless of interference with neighbors' supplies as long as there was no waste, malicious interference, or negligence. The correlative rights doctrine, which has thus far been applied in Florida and California, introduces the concept of mutual accountability or liability among ground water users sharing a common aquifer.

The prior appropriation doctrine as implemented in the western states, defines rights more explicitly by describing the specific use and amount of water available; priorities during times of shortages are established by time of application ("first in time, first in right"). The advantage of this is that a junior user knows what risk is involved when making an investment. In contrast, under the riparian and reasonable use doctrines, rights to use water may change from case-to-case depending on the circumstances. Yet experience with the prior appropriation system has demonstrated that the secure right is not always the one which contemporary society values. Thus, moving from the riparian doctrine to a prior appropriation doctrine does not solve the problem of liability in a satisfactory way, and most southern states have recognized this by rejecting prior appropriation (Putt 1978; Fisher 1958; and Maloney 1978).

---

[1] See John S. Lowe, Lon C. Ruedisili, and Bruce N. Graham, "Beyond Section 858: A Proposed Ground-Water Liability Management System for the Eastern United States." Ecology Law Quarterly 8 (1979): 131-61, for a discussion of problems stemming from the "rule of capture" inherent in these common law doctrines and a comparison of several alternatives for dealing with liability or accountability among users.

Permit systems deal with the issue of liability through planning--that is, the total water resource is evaluated and rights to use assigned and managed so that users do not interfere with each other's supplies (see Section 7.2.2, Permiting Systems). Modifications which have been proposed to clarify liability within the existing legal doctrines include a first user principle, a priority use rule, and a comparative cause rule (Lowe et al. 1979). The first user principle, similar to the prior appropriation doctrine, gives the superior claim to the first user in an area. This increases the certainty of the right over that of the "reasonable" test and requires little administrative structure; however, it has many of the disadvantages of the western system, e.g., it is often difficult to determine who was the first user and deferring to the first user may result in a less valuable use of the water.

A priority use rule would establish liability according to a preference system established by the state's legislature. In the case of injury to the higher priority user, that person could collect damages; if injury occurred to a lower priority user, that person would not be entitled to damages. In many southern states, a de facto preference scheme already exists. In Alabama, manufacturing and mining activities have been preferred (Putt 1978). The primary advantage of this modification is its usefulness for land use planning and overall planning for water quantity and quality. However, determining priorities and establishing guidelines for classification would require legislative commitment and administrative involvement. It might be difficult to alter these priorities as needs change, thus, reducing the flexibility of a state or local area. It also does not address the problem of conflicts between two similar interests--such as farmer against farmer.

A third alternative would provide liability in proportion to potential damages caused by all other uses. This rule recognizes that seldom is one user totally responsible for water disputes, especially for ground water conflicts. The apportioning of liability might be more politically feasible than the other suggestions because it seems to be a fair approach. It may be difficult to use, however, when the number of users involved is large. It also creates uncertainty regarding responsibility.

States may want to limit their intervention in water allocation issues, retaining the basic legal doctrines which currently exist while still providing a mechanism for the state to intervene where broader interests than those of the specific parties in conflict seem to exist (see Section 5.3.2 for a description of legal decisions affecting water allocations in the Southeast). Since these conflicts over water supplies are generally taken to state or federal courts as private suits, no mechanism exists for informing state policymakers of disputes over water use and for allowing the state to intervene in such disputes where evidence of the states' interests exists. One way to accomplish this would be to enact an intervenor statute, requiring notice to the state of any water disputes filed in the courts in order to give the state an opportunity to determine the state's interest in the dispute and to intervene where such interest seems warranted. This would allow individual choices to continue under common law doctrines and might be particularly appropriate in areas where supplies seem adequate with few conflicts developing over the local water resources. This option has been included in a group of recommendations to the Governor of South Carolina for changes in that state's water laws (South Carolina Water Law Review Commission 1982).

Other restraints on states and localities as they try to plan for effective water allocation to meet public needs in the future are the barriers to physical transfers of water which exist in both the surface and ground water doctrines.[1] A basic principle of the riparian doctrine is its restriction of water use to the riparian land. Thus, transfers across watersheds or even to nonriparian land are typically restricted in a case where such a transfer would interfere with uses of other riparian owners. The prior appropriation doctrine, while not restricting such transfers as a matter of law, has been modified by some states to restrict the place of use or the conditions under which transfers may occur so that transfers from one location to another are difficult (Cox 1982; Ballard, Devine, et al. 1982). The American rule of reasonable use and its modification, the correlative rights doctrine, also restrict the use of ground water to the overlying land; in contrast, the absolute ownership doctrine, now used only in Texas, places no restrictions on where ground water is used (Cox 1982).

---

[1] See Sporhase v. Nebraska, ex rel Douglas, 50 U.S.L.W.5115 (U.S., July 2, 1982) for a discussion of the basis for and potential limits to states' regulation of ground water. The majority held that ground water is of congressional interest under the article of commerce and that Nebraska's statutory reciprocity requirement for interstate transfers of ground water violated the Commerce Clause by posing an "unreasonable burden" on commerce. In part, the court reasoned that a state may use its police powers to regulate ground water for the protection of the health and safety of its citizens but not solely for the economic health of the state.

Riparian states and those with American or correlative rights doctrines for ground water can enact statutory amendments to existing water law to allow transfers to uses on other than riparian or overlying land so long as the uses meet the basic test of reasonableness as it is defined. This would put nonriparian uses on an equal footing with riparian uses in court evaluations. Similarly, ground water transfers could be specifically authorized (Cox and Shabman 1980). This option still begs the question, however, of the deficiencies in the "reasonablenss" test since it would be difficult to find areas in which withdrawals of surface or ground water for transfers do not cause at least some injury to other users in the area. However, it does establish the basis for negotiating or bargaining among those seeking transfers.

States in the Southeast, such as North and South Carolina, have experienced transfers or diversions of water despite common law limitations. The most typical example is an emergency provision law giving the state's Governor authority to allocate water for 30 days during extreme shortages (Heath 1978; South Carolina Water Law Review Committee 1982). States also provide for creation of public water districts or cooperatives which may actually divert water from overlying land or across watersheds or basins. In Alabama, the City of Mobile diverts its domestic water supply from the Escatawpa River, a part of which is under consideration for the national Wild and Scenic Rivers system. Although downstream users in Alabama were consulted, downstream users in Mississippi were not consulted and some have expressed objections that Mobile's withdrawals have contributed to low summer flows and resulting poor water quality. The potential importance of interstate agreements for the Southeast to provide a framework for problem-solutions is evident (Putt 1978; Heath 1989; Rhode 1983). Since transfers or diversions are generally prohibited only where injury is claimed, one alternative may be to create formal mechanisms such as basin or aquifer commissions to encourage negotiation or planning for the resource.

The more drastic step of severing traditional property relationships between land and water in the Southeast in order to create marketable water rights would likely be a politically difficult undertaking. While legitimate needs require that water be transferred away from use on the adjoining or overlying land, especially where population centers already exist in water scarce areas, the benefits from allowing land owners with water rights to sell their water to another are based on a strict goal of economic efficiency, ignoring social goals such as conservation, future uses, or aesthetic values.

In Arizona, water is now viewed as such an important resource that rights to use it no longer may be assumed to be part of land transactions. The state requires all new uses to be approved by application to the state regardless of prior rights and water rights may no longer be assumed to transfer with a land title

Chapter 9). This level of regulation requires a considerable institutional-administrative framework (Kyl 1982b).

Effective planning for water allocation at the local and state levels of government have also been constrained by the differing legal doctrines applied to surface and ground water. State planning as well as conflict resolution could be improved by changes in the law which recognize the connection between surface and ground waters. This could be accomplished by modification of the state's statutory definitions of waters to include recent developments in understanding hydrologic relationships. Without such statutory recognition, courts have not had a basis for including potential ground water impacts from surface water development, for example, in resolving conflicts among users. Thus, under the riparian doctrine, a particular use might seem reasonable as applied to surface water uses and yet interfere with ground water recharge. Although the courts are reluctant to adopt new concepts, they have done this where new information or understandings have made existing laws untenable in application. The issues and implications for states in treating surface and ground water as related resources--that is, conjunctive management--are considered in Chapter 9.

7.2.2 Permitting Systems

A. Description

Permitting systems are statutory provisions to require users of surface or ground water resources to seek governmental approval of use in the form of a permit (See Chapter 5 for a discussion of the Southeast's experience with permitting systems). These permits typically are issued by the states' water resources agency acting in a regulatory capacity. Permitting systems can be used to blend the best features of the western prior appropriation system with those of the common law doctrines of the East, resulting in a balance between state and individual interests. They may also be enacted as a comprehensive system replacing existing allocation doctrines, such as prior appropriation, riparian, and reasonable use, with governmental approval and coordination of all water rights.

Unlike the western states' appropriation which recognizes rights in perpetuity, time limits--e.g., 10 years or for the number of years over which investment in use can be amortized--generally are established. Georgia grants permits for 10 years, 20 years or up to 50 years where necessary for retirement of debt. State administrators typically have discretion in choosing among applicants for competing permits, although most states also have preferences established through constitutional, statutory, or judicial provisions. Permits usually are required for use in excess of a specific amount (e.g., >5,000, >50,000, or >100,000 gpd) and for specific purposes; they may require that new users not interfere with existing users and meet some type of broad "public interest" and beneficial use criteria. Permits also have been used to supply data for information and monitoring systems.

B. Current Status

Permit systems are used for ground water in South Carolina, North Carolina, Georgia, and Mississippi and often in conjunction with some type of capacity use area. The five Florida water districts all have authority to require permits for use--currently, the South Florida, Southwest Florida, and St. John's Water Management Districts use a permit system for allocation. Adopted in the late 1960's through the mid-1970's in response to concerns over ground water shortages developing in local areas, these systems have not been strictly or comprehensively applied. Even in those states which have capacity use areas, permits usually have not been revoked, modified, or denied to deal with shortages or quality concerns.

Specific requirements vary state by state; for example, Mississippi exempts all oil and gas activities as long as they have a state permit to operate. Georgia exempts agricultural activities from its permitting law. In North and South Carolina, permitting requirements were initially established for areas of the state determined to have ground man-agement problems. Recently, South Carolina has enacted legislation requiring the reporting of all ground water use in excess of 100,000 gpd, a law some believe to be an intermediary step toward a statewide permitting system. Georgia enacted a similar requirement for its major irrigators in 1982, requiring them to report their monthly usage once a year to the Cooperative Extension Agent who forwards the information to the Environmental Protection Division of Georgia's Department of Natural Resources (Kundell 1983).

The Florida Water Resources Act of 1972 specified the use of permits for all consumptive uses of surface or ground water. Permits in that state may be issued by one of the state's five local water management districts; otherwise, the district may chose to continue allocation under the existing common law doctrine. Other states (e.g., Minnesota, Wisconsin, and Maryland) also have adopted compulsory permit systems but, like many southeastern states, have created enough exceptions to weaken the comprehensiveness of the original legislation.

C. Advantages

Permit systems can greatly enhance the states' planning capacity by providing a centralized framework for information gathering and analysis and a mechanism for coordinating water quantity and quality concerns. In addition, because permits are issued for specific periods of time and for a quantified allocation, they provide reasonable security of physical supplies for the owners. This is an improvement over the common law doctrines which provided rights relative only to current demands by users. When conflicts develop in water scarce areas, the periodic renewal of permits increases the flexibility of administrators to respond to changing needs, especially in comparison to prior appropriation permits which have essentially been granted in perpetuity.

Issuance of permits also provides for development of resources based on current and future priorities and guidelines for resource protection. Information on uses supplied by permits can be used to monitor supplies in order to develop management strategies, especially where meters are installed and periodic reporting required. This can be invaluable as a conservation management tool during times of scarcity due to drought.

Permit systems do not have to interfere with market strategies if they are used only to designate initial quantified rights, leaving open subsequent sale or transfers of those rights among users within the bounds of the permit. For example, agricultural users would be free to sell their land and the specific quantity of water designated in the permit to an industry which wanted to locate in that area. However, states can decide to regulate these transactions; for example, Arizona has reserved the right to purchase water rights when land is sold in some areas of the state.

D. Disadvantages

Permitting systems require a well-staffed administrative agency; thus, some states would have to fund a new department or at least vest new functions in an existing agency at a time when states are facing budget constraints. Moreover, the procedural guarantees to ensure all competitors due process, compensation, etc. may make timely and efficient management difficult. In some cases, then, the permit process will not eliminate the conflicts over rights and priorities and may not provide significant improvement over current common law adjudication.

In contrast to the prior appropriation doctrine which grants rights in perpetuity (with some restrictions) and thus is attractive from an investment perspective, permit systems typically provide for renewable rights. The idea of providing permits which allow sufficient time to amortize equipment or recover investments is not necessarily an optimal solution. Although such a limited permit satisfies economic criteria, it fails to account adequately for other investment motives including long-term investment goals. If states substitute administrative discretion for water rights laws in the absence of clear guidelines, permit systems may increase the arbitrary, inefficient, and uncertain allocation of water among competing uses (Trelease 1974). In other words, legal uncertainties of water rights would to some extent be replaced by the administrative uncertainties of permits.

E. Feasibility

The fact that so many states have already adopted some type of permitting system, whether restricted or comprehensive, indicates the widespread recognition of the value of this approach. The major difficulty in implementing a comprehensive compulsory permit system in the Southeast may be the perception by existing users that the state intends to control water use across the board by replacing existing rights with a permit system. Putting the system in place would require substantial administrative capacity; however, it would not require a complete change in common law principles.

A permit system can be implemented in stages. An information gathering phase can be instituted initially to provide the state with a comprehensive picture of use patterns and major users. This information would then be helpful in developing criteria for allocation and standards during a period of public discussion. Specific measures to improve public acceptance could be incorporated, including grandfathering prior uses. This type of flexibility in implementation could enhance the state's effort to develop a concensus on the management of water supplies.

7.3 PROVIDE ADEQUATE SUPPLY

Because of the projected economic development and population growth in the Southeast, some areas are expected to experience surface and ground water shortages. Overpumping to meet competing water requirements for municipal, industrial, and agricultural uses can lead to problems that could affect the future growth potential of local areas (see Section 5.2.2).

This section discusses several structural options for increasing the amount of water available for use. In areas that are heavily dependent on ground water, the increasing stress on this resource might be lessened by reducing, or at least holding constant, the amount of water withdrawn. Several alternatives for for helping to ensure the availability of adequate supplies are briefly discussed, including the expanded use of surface water and the augmentation of ground water resources through well field development and mangement, desalination, and subsurface storage.

This is followed by a more extended discussion of artificial recharge of aquifers. Other options for increasing water availability, such as evaporation suppression and precipitation augmentation, are not discussed because of the need for further technological development or their limited applicability.

7.3.1 Expanded Use of Surface Water

As the Southeast has developed and its water requirements have increased, overpumping of ground water in some areas has lead to numerous problems (see Chapter 5). Expanding the use of surface water, from local sources or through transfers from outside the area of need, is one option for helping to relieve the strain on ground water resources while still providing adequate water supplies. For example, because of lowered water tables, higher pumping costs, and water quality problems, Myrtle Beach, South Carolina is considering using water from the Intracoastal Waterway as an alternative surface supply to its ground water resources (Spigner, Stevens, and Moser 1977; U.S. Geological Survey 1982; see Section 3.3).

Considerable surface water exists in the Southeast due to the plentiful rainfall--50 to 60 inches per year for most of the region (Geraghty et al. 1973). In addition to the natural rivers, streams, and lakes, additional surface water supplies could be developed by increasing the capacity of existing reservoirs or by constructing new reserviors. The storage capacity of reservoirs provides the flexibility of collecting water during rainy or high flow seasons for use during seasonal dry periods or extended drought.

Where adequate surface water supplies do not exist, already are allocated, or are not usable because of pollution, water diversions from outside the actual area of need might be possible. The transferred water could be fed directly into the water supply system, stored in local reservoirs, or pumped into a nonpotable aquifer for storage until needed.

Surface water resources could be used to supplement ground water withdrawals or to completely replace ground water as a source of supply. End uses that do not require high quality water--some manufacturing processes, agriculture, certain urban services such as park and golf course watering--could substitute lower quality surface water for ground water resources. Since approximately 70 percent of the population in the Southeast relies on ground water for drinking water supplies, using surface water for less restrictive purposes can help ensure that higher quality ground water is available as a source of drinking water.

Increasing the use of surface water can help alleviate the stress placed on ground water resources by reducing, or at least maintaining the amount of water pumped and/or the rate of pumping. This, in turn, will help maintain water table levels and reduce the potential for water quality degradation, including salt water intrusion and subsidence. For example, in an attempt to forestall further subsidence problems, parts of the Houston area have shifted from ground water to surface supplies from the San Jacinto and Trinity river watersheds. This has resulted in a drop in ground water pumping from 460 mgd in 1976 to 410 mgd in 1981 and allowed the city to shut down some of its well fields (New York Times 1982).

Whether sources are available locally or need to be transferred from outside the area, increasing the use of surface water as an option for providing adequate supplies has some disadvantages. For example, public acceptance of projects to increase surface storage by creating new reservoirs or expanding the capacity of existing reservoirs is frequently low because of the property loss and environmental damage involved. Active public resistance may make implementation of such projects difficult.

Some of the characteristics of surface water make it less attractive than ground water for many uses. First, surface water generally is of lower quality and more susceptible to pollution than ground water, resulting in treatment costs that can be high. Second, surface water is more subject to seasonal flow variation and drought; unless a very large source is available, the supply probably will not be as reliable as a ground water source (U.S. Environmental Protection Agency 1977). In some areas, local stream flows may not be adequate at any time of the year. For example, municipal and industrial requirements have led to overpumping and a lowered water table in northeastern Mississippi. However, stream flows in the area are not sufficient to permit an increase in the use of these surface sources as an alternative (U.S. Water Resources Council 1978). Third, occasionally the rights to water from sources such as surface impoundments have already been allocated and little or no additional water is available for use. For example, the entire water supply from Falls Lake Reservoir in North Carolina has been committed to the city of Raleigh. Other users in the area who are seeking surface water supplies would need to find alternate sources or request the State Environmental Management Commission to reassess the current allocation of the reservoir (North Carolina Department of Natural Resources and Community Development 1982).

Additional problems are associated with the interbasin or interdistrict transfer of water. Although the technology for the diversion of water is well developed, political constraints present a major barrier to the implementation of transfer projects. Under the common law application of the riparian doctrine which governs most of this region, water transfers outside watershed or basin boundaries (or even to nonriparian land) are prohibited where a transfer would interfere with uses of other riparian owners(see Section 7.2.1).

Although Florida is a riparian state, it has enacted legislation to permit the interbasin transfer of water as part of its overall water management efforts. The state water law includes a provision for transport across water management district boundaries if the transfer is considered to be consistent with the public interest and both districts approve. While transfers within a district are common in some parts of the state,[1] no transfers between two districts have yet taken place. However, the Southwest Florida Water Management District sponsored a study conducted by the Army Corps of Engineers to evaluate a transfer project to divert water 120 miles from the Suwannee River to the Tampa area. After considering the findings of the study, the district dropped the idea because of the distance and the high economic and environmental costs (Kemp 1982; Snipes 1983).

As the Southeast continues to develop and water requirements increase, alternatives to current ground water supplies will be necessary to support these demands in some areas. For example, industrial developments in Savannah, Georgia that use more than five mgd of water are required to secure their supplies from surface water sources (Ledbetter 1980). For those areas where surface water resources can be developed or where transfer projects are possible, the expanded use of surface water can help provide adequate supplies for localized areas and relieve some of the stress placed on ground water resources.

7.3.2 Well Field Development and Management

The increased development of ground water resources is one of the more obvious ways to provide additional supplies to meet increasing demands. However, as discussed in Chapter 5, uncontrolled pumping of ground water can result in the degradation of ground water quality, lower water tables and subsidence. Adopting a comprehensive well field management program can help ensure the reliability of supply while at the same time addressing the potential environmental impacts of a field's development and reduce costs through more efficient operation.

---

[1] For example, surface water is routinely transferred from Lake Okeechobee to southeast Florida to serve as recharge for the Biscayne Aquifer underlying Dade, Broward, and Palm Beach counties. On the east coast of Florida, water for Tampa is transferred from well fields located in Pasco County to the north.

Although some well field management generally exists through permitting for pumping rates, a more comprehensive management program needs to recognize the relationship between the two major components of the ground water supply system--the aquifer and the wells. In addition to pumping rates, such a management program would take into consideration well spacing, well depth, quantity of water to be withdrawn, and time of withdrawal. Factors external to the actual aquifer also should be considered, including: (1) the impact of supplemental supplies (e.g., from subsurface storage, desalination, or diversion of surface sources) on the water table and overall operating conditions of the well field; and (2) the implementation of land use restrictions to protect the field from contamination.

Thus, it is necessary to have information that is as accurate and complete as possible about the size, shape, volume, flow, and recharge of the aquifer. This facilitates decisionmaking about well field placement and development that will maintain the aquifer within its limits of recharge. Together with projections of future water demands, this type of information is useful in determining the feasibility of taking advantage of the economies of scale that accompany the regionalization of water supply and treatment facilities. Rather than many small facilities (1 to 2 mgd), a few large 15 mgd facilities are used.

Unfortunately some of the necessary information may not be available for a particular aquifer, which could lead to less than efficient management. For example, without information about the location and characteristics of the recharge area, it is very difficult to determine safe yields for the supply system. The communities of Sanibel, Pine Island, and Cape Coral, Florida all use water from the artesian Hawthorn aquifer. The precise recharge areas of this aquifer, the rate and direction of water flow, and the amount of water available for use are not known. Consequently, well field development must proceed cautiously with careful evaluation of the effects of the well field on the users of the resource (VanArman 1979).

In order to have an effective ground water management system the components need to be monitored and their interaction assessed. Consequently, routine procedures should be established to monitor the performance of each well to determine their operating efficiency. The capacity of a well field is not defined by the summation of the individual pump ratings. Among other things, the effects of well spacing and the interference of one well with another must be considered and a pumping rate and sequence developed that generates the most water at the least cost and with minimal environmental impacts.

A well field development and management program, then, must be designed for the water requirements of the area and with the specific characteristics of the aquifer and wells in mind (Simpson

1978). Thus, supply systems with different characteristics that are providing water for different end uses are likely to have very different well field management programs. The need to tailor each management program to local conditions and the general lack of transferability of programs could be a constraint to the development and implementation of comprehensive well field management. Further, the feasibility of any management program is determined, in large part, by the availability of the necessary structure--laws and institutions--to implement the program. As noted in Section 7.2 and Chapter 9, comprehensive ground water management systems are not widespread in the Southeast.

7.3.3 Desalination[1]

Sea water and brackish water, which contains a lower concentration of dissolved solids than sea water but which still is too concentrated for drinking or irrigation, are found in or near many areas of the Southeast where fresh water supplies may need to be augmented. Desalination processes currently available or under development can convert saline or brackish water into potable water that meets or exceeds EPA drinking water standards. The product water can be used to supplement other water supplies in the following ways:

- Adding necessary quantities of potable water during drought, critical, or peak periods;
- Mixing with water withdrawn from a source that may have been degraded to make up a supply capable of meeting quality standards;
- Serving as the sole source of water during conventional plant breakdowns, or in the event pollution episodes do not allow continuous pumping from an alternate source; and
- Providing water at less than drinking water standards for nonpotable uses such as irrigation, industry, or urban services.

Desalting methods can be divided into two classifications: (1) those that use a phase change (distillation and freezing) and produce relatively pure water vapor or ice crystals; and (2) those that separate water and salt ions within the liquid phase by using electrodialysis, ion exchange, or reverse osmosis. The electrodialysis and reverse osmosis processes are used most frequently.

---

[1] This discussion is based primarily on South Florida Water Management District (1977) and U.S. National Water Commission (1973).

Florida has six commercial desalting plants--three using electrodialysis and three using reverse osmosis--with a total capacity of approximately seven million gallons per day. In addition, 32 smaller plants in the state use distillation, electrodialysis, and reverse osmosis processes. A tenfold increase in the number of reverse osmosis units is projected for the year 2000. Desalination plants also are in operation in Arizona, California, New Mexico, Texas, and Wyoming.

One of the major advantages of this option is that the sources of feed water generally are not affected by the conditions that led to the need for more supplies in the first place--extended drought, population and industrial growth, and pollution. However, even where feed water is available, the high cost of implementing some of the techniques is a barrier to their adoption. Due in large part to the energy requirements of the distillation process generally used for the conversion of highly saline water, the South Florida Water Management District estimates the cost of product water using sea water as a source to be about $3.50 per 1,000 gallons. Some alternatives are available for reducing the overall costs, including: (1) more efficient energy use; (2) operation on off-peak energy; (3) economies of scale, reduction in unit costs through increases in plant size; and (4) staged construction to meet increases in demand as it grows.

Not all techniques are as costly as the distillation processes. Based on the experience of the Florida plants, the average base price per 1,000 gallons of product water from brackish water produced by reverse osmosis and electrodialysis techniques was $0.63 and $0.73 respectively, excluding distribution costs. By comparison, the average price charged to customers in Palm Beach, Broward, and Dade counties, Florida per 1,000 gallons of water from conventional sources was $1.05, $1.36, and $1.20 respectively.[1]

In addition to cost considerations for some techniques, the potential environmental impacts are a disadvantage in some areas. Desalination produces a concentrated brine stream and disposal of this brine could lead to environmental problems. For example, the effluent from a 10 mgd sea water plant will contain about 2,000 tons of salt residue daily. Where brine discharge can be made to the sea, disposal problems are relatively minor. Inland sites must rely on evaporation ponds, transport to a salt water body, deep well injection, or central stock piling of dry salts. Further, the characteristics of the aquifer to be used for feed water and of the overlying strata frequently are not defined sufficiently to determine the impact of a large number of wells.

---

[1] These costs include the nominal profits the utility companies are permitted to earn on their investments in addition to distribution costs.

However, in those areas where the potential environmental impacts have been controlled, the relatively low cost of reverse osmosis and electrodialysis make these techniques attractive options for ensuring adequate water supplies. Although desalination is not likely to be used as the sole source of water for an area, it can be integrated with current water supply systems to provide protection against drought conditions.

7.3.4 Subsurface Storage and Retrieval

The injection and storage of excess water in saline aquifers has the potential for providing large quantities of supply for retrieval during dry seasons or under drought or crisis conditions. This option could be particularly useful where surface impoundments and fresh ground water resources can not be expected to provide adequate supplies during dry seasons or drought years. Water withdrawn from storage in a saline aquifer could be used to:

- Supplement urban water supplies through direct use or recharge to a fresh source aquifer;
- Supplement agricultural, industrial, or domestic irrigation supplies;
- Supplement stream flows; and
- Maintain fresh water heads in areas threatened by saltwater encroachment (South Florida Water Management District 1977).

Conceptually, the use of underground storage and retrieval as a source of supply is relatively straightforward. During times of plentiful rainfall, excess fresh water is pumped into a saline or nonpotable aquifer and stored until needed. When the stored water is required, the free flow of the recovery wells generally will result in an adequate rate of discharge. The water is allowed to flow until it is no longer needed or until the quality of the mixed fresh water and native formation water being discharged is not acceptable. The injection, storage, and retrieval cycles can be repeated indefinitely.

Efforts to develop injection, storage, and retrieval techniques have been underway for quite some time. In a 1946 test, water was injected for 85 days into an aquifer at Camp Peary, Virginia and results of the withdrawal phase were reported as encouraging (Cederstron 1957). Moulder and Frazor (1957) conducted field tests at the McDonald well field in Amarillo, Texas, and Brown and Silvey (1973) conducted injection and storage tests in a brackish water aquifer underlying Norfolk, Virginia. Approximately 85 percent of the injected water in the Virginia aquifer was recovered and met U.S. Public Health Service drinking water standards.

More recently, tests have been conducted in south Florida to evaluate the feasibility of storing fresh water in the saline Floridan Aquifer. Encouraging results have been obtained from major field investigations near Jupiter in Palm Beach County and the City of Miami's Hialeah well field. For example, 50 percent of the 85 million gallons injected into the Floridan Aquifer at the Hialeah field was recovered after a storage period of 55 days. The water was withdrawn at the rate of 500 gallons per minute. Injection well tests conducted by the U.S. Geological Survey have indicated that 50 to 75 percent of the potable water can be recovered (South Florida Water Management District 1977; Meyer 1982).

The subsurface storage of fresh water has many advantages, including a decrease in the loss of water due to runoff during the wet season and increased availability of fresh water during the dry season. This option has other advantages compared to alternative methods for storing water, such as surface impoundments. Since the water is stored below the ground, evapotranspiration--a significant source of water loss--is eliminated. If the aquifer in which the fresh water is to be stored covers a large area, storage can take place close to the points of need and reduce requirements for extensive pipeline systems to transport the water potentially long distances from surface resources. In addition, most subsurface storage would take place in artesian aquifers with little need for additional pumping facilities to withdraw the water. Large land areas and costly structures are not necessary for subsurface storage and adverse environmental impacts would probably be negligible. Finally, depending on the characteristics of the particular aquifer, the temperature of the withdrawn water can be expected to be relatively stable because of the thermal isolation properties of aquifers (South Florida Water Management District 1977).

Although this option has many advantages over other potential augmentation options, the injection, storage, and withdrawal of fresh water has potential problems. The viability of subsurface storage depends to a great extent on the percentage of injected water that can be recovered for use. The greatest problem is the difficulty of predicting how much usable water can be recovered from a particular aquifer. The recovery rate is highly dependent on the hydraulic characteristics of the aquifer which only can be evaluated through extensive field testing. Consequently, information required to determine the viability of the option for a particular location may not be available. The generation of such information can be a slow and costly process.

The cost of implementing this option would be determined, for the most part, by the characteristics of the aquifer, the desired storage capacity, and consequently, the number of wells required. Since the receiving aquifer is under pressure, it is necessary to pump the fresh water down against the aquifer head. The greater the pressure, the larger the pumps required and the greater the expense involved.

The institutional arrangements for operating a subsurface storage system could vary depending on the extent and location of the facilities. If a deep aquifer storage system were operated in conjunction with an existing well field, the utility responsible for the well field also could operate the storage facility. If storage sites were widespread and located other than at existing or future well fields, a regional authority could be created that would operate the facilities and oversee the distribution of water to the various users--local utilities, agriculture, and industry. However, local resistence to such an authority would likely develop if the regional authority entered into competition with local utilities and directly supplied customers of the utilities.

7.3.5 Artificial Recharge of Ground Water

A. Description

Another option for increasing the amount of available ground water is through artificial recharge--intentionally augmenting the natural movement of surface water into underground formations (Todd 1980; Lehr 1982). In addition to maintaining or augmenting the natural ground water as a useable resource, artifical recharge projects can be used to combat the adverse impacts of overpumping identified in Chapter 5. Such projects can reduce, and in some cases reverse, declining ground water tables, increase well yield, improve water quality, protect coastal aquifers against saltwater intrusion, and reduce or stop significant land subsidence (Asano and Wasserman 1980; Lehr 1982).

The water to be used for recharge can come from various sources, including storm water runoff, industrial air conditioning return flows, and local or imported surface water. Reuse of wastewater has received increasing attention in recent years. Aquifer recharge with wastewater that has undergone secondary and sometimes tertiary treatment is becoming an important component in water management planning in California, Arizona, and New York (Schmidt et al. 1978; Asano and Wassermann 1980).

There are two basic methods for increasing the amount of water entering a ground water reservoir--percolation and injection.[1] Surface spreading is the most widely practiced form of percolation and consists of releasing water over the ground surface to increase the amount of water infiltrating to the water table. Surface spreading methods include:

---

[1] For a more complete description of the various ground water recharge methods, see Todd 1980, Chapter 13.

- Basin construction--water is recharged through basins formed by dikes, levees, or excavation;
- Existing stream channels--operations to increase the time and area over which water is recharged from an existing stream, including management of streamflow and modifications to increase infiltration;
- Ditch and furrow--water is recharged by using a series of shallow, flat-bottomed, and closely spaced ditches or furrows; and
- Flooding--water is released in areas of relatively flat topography to spread evenly over a large area and at a minimum velocity to avoid disturbing the soil.

In areas where the composition of shallow subsurface strata restricts the infiltration of water spread on the surface, pits and shafts can effectively reach materials with higher infiltration rates (McWhorter and Brookman 1972). Use of abandoned excavations, such as gravel pits, can reduce the cost of using this percolation method.

Injection wells also can be used; water is pumped under pressure directly into the ground water zone. A cone of recharge is formed that is similar in shape but is the reverse of a cone of depression that forms around a withdrawal well (Todd 1980). Injection wells are particularly useful when it is necessary to recharge a deep, confined aquifer or where limited space is a consideration, such as in urban areas (Roberts 1980).

Both percolation and injection permit direct infiltration of surface water into the ground water reservoir. The actual recharge method used at a particular site will depend, for the most part, on the purpose of the recharge project and the geologic and hydrologic conditions at the site, including: the thickness and permeability of the material overlying the aquifer, quality of the recharge and native aquifer water, the quantity of water involved, and the characteristics of the receiving aquifer (Lehr 1982; Kincannon and Tiederman 1972). For example, in areas where the materials overlying an aquifer are thick and have a low permeability, injection wells are the most likely technique. On the other hand, where thin or more permeable material is found, surface spreading through basins, flooding, or ditches and furrows may be preferable. Topography also is an important feature to be considered. Water spreading techniques require a relatively flat land surface, while an injection well system is not influenced very much by topographic relief.

B. Current Status

Artificial recharge is practiced in many areas of the United States where ground water is a major supply source or where these resources are being depleted; in California alone, approximately 300 artificial recharge projects operate in areas where ground water has been extensively exploited (Todd 1980). Surface spreading is one of the most widely used recharge techniques. For example, the Los Angeles County Flood Control District uses chlorinated secondary effluent from three treatment plants (San Jose Creek, 15 mgd; Wittier Narrows, 12 mgd; and Pomona, 2 mgd) for ground water recharge. The effluent is mixed with imported fresh water and local runoff and percolated through basins to replenish the Montebello Forebay Aquifer east of Los Angeles. The reclaimed water supplies about 10 percent of the total annual recharge and is used for municipal, industrial, and agricultural purposes (Schmidt et al. 1978; Culp, Westner, Culp 1979). Studies of recharge from basins also have been conducted in Washington, Arizona, Iowa, Massachusetts, New Jersey, and New York.

Pits also have been used for many years to increase infiltration and percolation. Since 1951, pits have been used in Peoria, Illinois, to penetrate the shallow sand and gravel aquifer serving well fields in the area and recharge chlorinated river water (Todd 1980).

Ground water recharge by injection is practiced, for the most part, where the aquifer is deep or where land use or topography make land spreading techniques impractical. For example, more than 2000 recharge wells capable of accepting flows of up to 5.3 mgd are located within the Snake River plain of southern Idaho. The geology of the area consists of alternating layers of fractured basalt and is not condusive to surface spreading methods (Graham 1977). Other successful injection projects are in operation in New York (Schmidt et al. 1978).

One of the best examples of the use of the injection method is the Water Factory 21 facility operated by the Orange County Water District in southern California. The purpose of this 15 mgd system is to prevent saltwater intrusion and replenish local ground water supplies. Secondary effluent is given advanced treatment, including desalination by reverse osmosis, and injected into the ground water system at the rate of 20 mgd. Ten percent of the reclaimed water repels saltwater intrusion and the remaining 90 percent becomes part of the water supply of neighboring communities (Manwaring and Heaton 1981; Schmidt et al. 1978). Future ground water recharge projects have been identified that would introduce approximately 232 mgd of reclaimed water through percolation and injection into California ground water basins used for domestic water supplies (Asano and Wasserman 1980).

C. Advantages

The advantages of artificial recharge as a means of augmenting water supplies are similar to those of storing water in saline aquifers (See 7.3.4). For example, surface storage is subject to evaporation and pollution that can be avoided through the use of underground sources. Further, suitable sites for surface reservoirs may not be available or environmentally acceptable; even if they are, the cost of recharge may be lower than the cost of equivalent surface reservoirs (Asano and Wassermann 1980).

When the percolating or injected water reaches the aquifer, the aquifer serves as a natural distribution system and reduces the need for surface pipelines or canals. In addition, some ground water recharge methods can result in enhanced water quality. Percolation and subsurface flow can remove some contaminants and retard the movement of others, resulting in quality improvements that reduce the health risk of potable use (Bell 1981; Roberts 1980). Thus, depending on the characteristics of the aquifer and the contaminants involved, it may not be necessary to satisfy drinking water standards prior to recharge; artificial recharge could result in the cost-effective removal of contaminants, or at least reduce the level of treatment required after withdrawal (Roberts 1980).

Artificial recharge is particularly useful for dealing with the problems that can occur as a result of ground water overdraft--lowered water tables, subsidence, and saltwater intrusion. Thus, this option not only provides an alternative for increasing supply, it also can help improve water quality and allieviate the impacts of overpumping.

D. Disadvantages

The major disadvantages of artificial recharge result from the need to guard against undesirable health impacts on the users of the recharged water. This is particularly the case when wastewater is the source of recharge water and potable use is expected. Tertiary treatment generally is required if reclaimed water is to be injected directly into an aquifer; if percolation techniques are used, secondary treatment is most frequent but the actual level will depend on the characteristics of the overlying strata and the level of contamination (Schmidt et al. 1978). In any case, substantial costs can be incurred in preparing wastewater for the recharge process. To the degree that surface water sources or storm runoff are the recharge supply, the need for advanced treatment and the resulting costs may not be as great.

Additional costs also result from the lack of information available about the characteristics of many aquifers. Studies and tests are required in order to determine the ability of the aquifer to receive artificially induced water and to determine the fate of pollutants in the aquifer.

Numerous studies have been undertaken, primarily in California and Arizona, in an effort to determine the potential water quality and health impacts of ground water recharge operations (Schmidt et al. 1978; Asano and Wassermann 1980). For example, a Stanford University project is attempting to evaluate the extent of movement of trace organics through an aquifer from a recharging well. Data from the study indicate that in some instances, movement through subsurface strata may attenuate residual organics introduced directly into an aquifer during artificial recharge. However, the degree of attenuation depends on the nature of the aquifer material and the type of contaminant (Shew and Dunlap 1981). More complete information about the potential health impacts of this option will be necessary before widespread use of the product water of artificial recharge systems is likely to make a major contribution to potable supplies.

Once the recharge is underway, monitoring wells are necessary to determine the direction and rate of movement of recharged waters and the extent of water quality changes (Roberts 1980). As noted in Section 4.4, ground water monitoring is more difficult and costly than monitoring surface water systems.

E. Feasibility

The potential for ground water recharge does not appear to depend as much on engineering developments as it does on health and regulatory issues (Asano and Wassermann 1980; Schmidt et al. 1978). Although ground water recharge for agricultural use is widely accepted as safe and cost-effective, considerable controversy exists as to whether and under what conditions potable reuse should be permitted, particularly when wastewater is the source of the recharge (Roberts 1980). In many areas, the ground water resource is the major reliable water supply and its quality must be maintained at a level suitable for domestic use. As noted in the discussion of disadvantages, studies are underway to determine the risks involved with using artifical recharge techniques.

Adoption of artificial recharge could be delayed in some areas because many agencies with varying interests would be involved. Relevant interests could include state, county and local health departments, the water resource agency, the public utility commission, and state and local environmental protection agencies. For example, confrontations that are not easily resolved could occur between the health departments and the water resource agency due to differing priorities and legislative mandates. Such inter-agency conflicts are not unique but would have to be dealt with for artificial recharge to be feasible.

The use of artifical recharge as an augmentation option is also constrained by the propensity, particularly by the Corps of Engineers, to deal with water problems by constructing surface water projects. Although more attention is being given to the use of comprehensive water management, including ground water alternatives, major construction projects (e.g., dams, reservoirs, pipelines) are still viewed by many as the most appropriate solution to water supply problems (Bennett 1982).

Another potential barrier stems from the very conditions that required artificial recharge in the first place--water shortage and competition for its use. Where wastewater has been returned to a stream in the past, downstream users may suffer reduced flows if the wastewater is used as a source of supply for artificial recharge. Since water reuse is relatively new in many states, no clear basis in legislation or court decisions exists to decide water rights issues for reuse projects like artificial recharge. Whether or not the downstream users have any rights, they may be an important political factor with respect to the adoption of an aquifer recharge program (Manwaring and Heaton 1981).

Public acceptance also could be an obstacle to the adoption of some recharge methods. While an injection well may not present much of a problem, land spreading methods could generate opposition from neighborhood groups if a facility is planned for their area. The use of large lagoons or fields for water spreading to recharge an aquifer could be viewed as undesirable, particularly if wastewater is the supply source. Opposition could result from fears that water spreading methods would be unsightly, accompanied by noxious odors, and lead to local health problems. Nevertheless, artificial recharge is particularly well-suited to those areas of the Southeast where saltwater intrusion is a major concern or where ground water is the major source of supply and demands are heavy.

7.4 MANAGE DEMAND

Because of rapid growth and development, some areas of the Southeast are experiencing demands for water that approach or exceed the available supply. In addition, periodic droughts can create "short-term" local shortages almost anywhere. In 1980, drought in the Mid-Atlantic regions forced many communities to reduce water consumption through water rationing (Conservation Foundation 1982). In addition to well-developed alternatives for the allocation of water and options for increasing the amount of water available for use, the provision of adequate water supplies can be aided by managing demand.

In this section, conservation, pump taxes, and pricing alternatives are discussed as options for managing demand. Although these options do not physically increase the amount of water available, they accomplish the same end by reducing water requirements. Conservation options can range from voluntary to mandatory strategies and apply to all end use sectors. Technical options for agricultural, domestic, and industrial conservation are discussed, followed by the role of public education in water conservation. Economic incentives also can be used to help control demand. The use of pump taxes is discussed as an option that can be applied to self-supplied users, particularly rural and industrial users, and water pricing alternatives are discussed as an option for managing municipal demand.

7.4.1 Conservation

A. Description

Conservation of water can be an effective option both for reducing demand in the short-term and for ensuring available supplies to meet long-term growth needs. It also can make a substantial contribution to improving water quality by reducing the amount of discharges. Conservation alternatives are available for every type of use, including residential consumers, business and industry, and agriculture. For example, some states and local governments have used public awareness campaigns to reduce overall water consumption; others have required the use of water conserving plumbing fixtures and appliances in new construction starts and encouraged the retrofitting of such devices in older homes and buildings. Public and private water utilities have used new policies designed to achieve conservation goals as well, including metering, improved distribution systems, and alternative rate structures (see Section 7.4.3). Business and industry have used employee education programs and modified process designs to reduce total water consumption or permit recycling of wastewater. The agricultural sector has conserved through irrigation methods and, more recently, through limited use of treated municipal wastewater for irrigation supplies.

The choice of strategies for achieving conservation goals depends on particular local conditions and priorities, including the source of water supply, characteristics of heavy water users, and seasonal demands of an area. Because some sectors tend to use ground water in greater quantity than others, the local importance of a particular sector's potential contribution to ground water conservation must be assessed.

Farmers in the Southeast have become increasingly aware of both the benefits of irrigation and the conflicts which can result from increasing demands from the residential and industrial sectors. Thus, as farmers look for ways to make better use of available water supplies, more efficient methods or irrigating and improved water management are available to them. These methods are based on research, development, demonstration, and commercialzation efforts already under way. For example, the University of Georgia's Agricultural Experiment Station in Tifton is conducting a 6 million dollar research project on irrigation supported by the Mellon Foundation (Kundell 1983).

Drip or trickle irrigation is potentially a major water conservation practice, offering estimated irrigation efficiencies (ratio of volume of water stored in the root zone and used by the crop to the volume delivered to the farm's system) of 75 to 95 percent. This method uses small-diameter plastic tubing to deliver water to near the plant. The water is usually discharged at a rate less than the soil's capacity for infiltration through small holes in the tubing. The tube itself can be laid on the the surface, buried or supported slightly about the surface (U.S. Dept. of Interior, 1979).

Sprinkler irrigation, with estimated irrigation efficiencies ranging from 50 to 85 percent, uses a variety of systems to scatter water across an acreage. Older systems have to be moved by hand to alternate applications. The newer mechanical sprinkler systems include the center-pivot, self-propelled booms, and side-roll sprinklers. The center-pivot sprinkler applies water from spray heads on a pipeline supported on mobile towers above the crops. The pipeline is fixed at one end to the pivot where it connects to the water supply. Controls on the towers regulate the pipeline's movement in an arc about the pivot. These sprinklers are typically one-fourth mile long and irrigate a 135 acre circular field; however, the newer models can irrigate in square patterns (U.S. Dept. of Interior, 1979).

Research and development efforts have led to the use of low-energy precision application (LEPA) systems that use mobile drip units with drop tubes reaching every furrow as the system moves laterally through the furrows. The systems can be operated at 99 percent application efficiency and can reduce energy use by 90 percent compared to rotating pivotal sprinkler systems (Lehr 1983).

The oldest method of irrigation is surface irrigation, which applies water to the edge of a field allowing it to infiltrate as it flows across or settles. This can be accomplished through use of furrows, graded border, contour or border ditches, wild flooding, etc. Estimated surface irrigation efficiences range from 30 to 65 percent (U.S. Dept. of Interior 1979).

Even the older surface flooding techniques can be vastly improved through use of a land leveling system. Eliminating hills and basins in a field greatly reduces the amount of loss due to runoff as well as contamination of streams with pesticides and fertilizers. Laser-controlled land leveling has reportedly brought surface irrigation efficiency levels up to 90 percent. After a land grade levels a field in a gross way, a receiving unit mounted on the land grader automatically positions the blade at the highest point designated by a tripod-mounted laser; with this technology, a two to four acre field can be made level to within 10-15 millimeters (Lehr 1983).

The choice among these types of irrigation will depend on the soil characteristics, crops to be irrigated, water supply, labor availability, and economic and environmental constraints. None of these methods are consistently more efficient than the other; in fact, more than one method may be appropriate in a particular area.

Farmers also can control the rate, amount, and timing of water application to reduce ground water overdraft and improve water quality while still improving crop yields. Switching to crops which use less water or provide higher cash sales can also fit into a water management plan. These require knowledge of soil moisture, crop water requirements, and rainfall to determine moisture balance. Farmers also can contribute to overall conservation goals by using wastewater from municipal treatment plants for irrigation purposes in lieu of pumping high quality ground water for irrigation.

Conservation efforts for domestic users include media campaigns to create change in use patterns, the installation of water-saving devices on shower heads and toilets, the use of dyes to detect water leakage in toilet tanks, sale of water-saving appli-ances, the installation of water meters, increases in the unit price of water, and mandatory reduction in use of water for exterior purposes. Media campaigns reflecting the particular goals of the local conservation effort can range from general state-wide public awareness campaigns highlighting the importance of water to an intensive local campaign using all media, distribution of free conservation kits with plumbing flow restrictors, and changes in rate structures.

In residences, older flush toilets typically are the largest water users, averaging about five gallons per flush (Sharpe 1978a). New toilets have demonstrated an 18 percent reduction in water use (Schuelein 1981). Retrofit devices, such as placing plastic bottles, bricks, or "water dams" in tanks, maintain static head and velocity of the water while reducing the volume used by up to 25 percent. Faucet and shower heads which also deliver more water than is needed, can be retrofitted with low-flow fixtures; flow also could be controlled by a flow-restrictor attached to the water line. Automatic dishwashers and clothes washers are also heavy water users; some newer models use up to 70 percent less than the older ones. Retrofitting older models is not practical, yet some savings can be achieved through more efficient use of the machines (e.g., only using them for full loads) (Schuelein 1981). Pressure reducing valves can be placed on the main supply line to houses where water pressure is high (Sharpe 1978).

In some residential areas, a large portion of water is used for exterior purposes, especially lawn and garden irrigation, car washing, and swimming pools. Planting native species which can accept local climatic conditions and improving sprinkler methods to include timing and soil moisture testing are two strategies for using exterior water efficiently.

Public and private water suppliers can utilize both supply and demand management strategies to help achieve residential water conservation. Conserving supplies can be achieved through improved monitoring of the actual distribution through metering and computerized delivery control systems; improved leak detection and repairs to the distribution system; overall pressure reduction during peak demand periods; and overall watershed management to protect against contamination, overpumping and evaporation loss (Stone 1978; Schuelein 1981). Reductions in demand can be achieved through through water pricing, regulation, and education. Effective water pricing requires meters for consumption accountability and regulation requires established sanctions and an enforcement mechanism. Education is usually a supplementary strategy for achieving conservation goals (Schuelein 1981).

Manufacturing and power plant cooling are among the major water users in the Southeast. Over the past decade stringent federal, state, and local water quality regulations as well as the cost of water in some areas have created incentives for industry to conserve water by recycling and reusing process water that was formerly discharged as wastewater (Atlanta Regional Commission 1980; Levine 1982). Industries also can purchase wastewater directly from municipal waste treatment plants as a source of water for process use, thereby participating in a water reuse program.

In addition to these voluntary efforts to use water more efficiently, both business and industry are responsive to many of the same strategies used in the domestic and agricultural sector. For example, if industry is supplied and metered by a private or public utility, it will be directly affected by changes in pricing per unit or rate structures. Business and industry can also utilize water conserving plumbing appliances in new construction or for retrofitting existing facilities. If industry is using ground water as a primary source, states can use pump taxes in the same way they are utilized for agriculture (see sections 7.4.2 and 7.4.3 on Pump Taxes and Pricing).

Public education is a long-range strategy to promote conservation among all water users. The major goals of such a program are to increase public understanding of water issues, to raise awareness of the need for water conservation, and to orient the attitudes and behavior of water users toward saving water. Public education and information programs typically are supplements to other conservation options such as pricing, pump taxes, and other direct regulation or restrictions on use. Public education and information, as an integral part of a state's water conservation plan, would ideally have a direct budgetary allocation with agency resources dedicated specifically to such work rather than developing it as an ad hoc program.

Specific implementation strategies for public education and information depend on the particular conservation goals of the state or local area and the existing public attitudes toward conservation. An essential feature of public education and information programs is the preliminary work of identifying key user groups (e.g. domestic, industrial, agricultural), policymakers, and managers and assessing current attitudes toward conservation in general and likely receptivity to particular strategies.

Areas which adopt a long-range, year-round conservation approach would develop on-going public education programs incorporating both general information about water conditions and the need to conserve. Areas with immediate problems such as severe droughts, land subsidence, or overpumping would depend on a more intensive, hard-hitting approach designed to achieve short-term change in use patterns. Specific strategies can cover a range of media, including direct-mail of brochures, use of news media for publicity, distribution of water conservation kits, classroom education program for schools, technical assistance for business and industry, speakers bureau, etc.

B. Current Status

In the agricultural sector, farmers in the Southeast currently have access to experts in agricultural practices through agricultural extension agents at the county level, at the state university systems, as well as the soil and water conservation districts to assist them in developing an improved water management plan. However, a gap exists between actual practices and state-of-the-art as defined through research because of the economic constraints involved in adopting new, costly technologies as well as more general environmental, social, and political constraints (U.S. Dept. of Interior 1979).

The state of California, recognizing that irrigated agriculture is the sector with the largest potential for water savings, is developing the California Irrigation Management Information System with the objective of providing updated data on crops and weather for farmers. Although used primarily by commercial irrigators, efforts are being made to reach individual farmers. A mobile lab travels around the farming areas to contact individual farmers about innovations in irrigation and crop management. Research continues on ways to improve water use in agriculture (Robie 1982). A number of other commercially available computer systems and consulting operations are available to farmers as well as a variety of sensors, ranging from microwave sensing from satellites to neutron probes and infrared sensors, to help framers manage their water application systems.

Nonetheless, farmers have been slow to adopt more efficient irrigation practices; for example, trickle irrigation is now used on less than one percent of irrigated U.S. acreage despite studies showing that it uses less than half the water used by sprinkler or surface flooding systems and offers added advantages in insect and weed control and reduced runoff (Lehr 1983).

Conservation practices affecting domestic users have been adopted across the United States. In the western U.S. which has had a long experience with water shortages, cities, water utility districts, river basins, and states have implemented a variety of water conservation strategies. Both California and Colorado have wastewater reuse demonstration projects under way to produce usable water for irrigation, plant cooling, and landscape maintenance (Wilson 1978; Work et al. 1980). Denver, Colorado implemented mandatory water conservation and tap allocations during the summer of 1977 to deal with a drought (Miller 1978); Arizona has included goals for reduction of per capita consumption in municipalities as part of its newly adopted water management plan (Kyl 1982a; 1982b). Los Angeles has implemented a major leak detection program begun in 1976 as a conservation measure (Kingston 1979).

In the Southeast, Georgia and Florida have enacted legislation requiring toilets, faucets, and shower heads to be water conserving. In Georgia, the Atlanta area already has begun to adopt ordinances to enforce the legislation and provide exemptions and penalties (Atlanta Regional Commission 1980). In Florida, the South Florida Water Management District (1982) has formulated a Water Shortage Plan which has been implemented on a voluntary basis but can become mandatory and enforceable by the District. This plan covers all users--private and public utilities, their consumers and those pumping ground water from private wells--and combines reductions in use with timing of use to achieve conservation goals. Economic incentives have been implemented by many municipalities as a means for encouraging or even forcing conservation (see Section 7.4.3). Dallas, Texas places a surcharge on residential customers during periods when their peak demands exceed a specified target (Rice and Shaw 1978).

Comparison of residences with septic tanks and those with hook ups to sewer lines show that septic tank owners typically use less water in their homes. This is likely a result of their concern over the maintenance and cleaning of the septic tank (Schuelein 1981). Since many rural residences which depend on ground water also are using septic tanks, conservation of water in these areas already may be occurring at rates which would meet state or local per capita goals typically set for residences receiving water from municipal suppliers. A study of rural users in Oklahoma has shown a relationship between age and experience with septic tanks and reduced water use (Larson 1982).

During the past decade, industries have made major efforts to reduce waste discharges by redesigning plant processes and reusing wastewater. These changes have, in some cases, reduced water consumption as well the water treatment load at municipal sewage treatment plants. U.S. industry, on the average, satisfies more than half of its requirements through internal use and consumes less than 5 percent of its total intake. In 1975 industry recycled about 82 billion gallons per day (bgd) out of the 140 bgd it required (Weinberger 1978; U.S. EPA 1979). Direct piping to industry of water from municipal wastewater treatment plants also has been tried. In Baltimore the city's wastewater is being directly reused for cooling by Bethlehem Steel (U.S. EPA 1979). This approach can reduce demands for water of high quality, leaving it for domestic consumption.

In Oklahoma the cities of Tulsa and Enid have contracts with industry allowing them to use the return flow from wastewater treatment plants; the Oklahoma Gas and Electric power production plant in Tulsa depends totally on the city's wastewater for cooling (Sullivan 1982). California has actively supported wastewater reuse by industry, although it only accounted for 5 percent of the volume of wastewater reclaimed in that state in 1977. Most wastewater reuse went to irrigate crops not intended for human consumption (57 percent), landscape irrigation (14 percent), and ground water recharge (14 percent) (Brown and Weinstock 1981).

In Attleboro, Massachusetts, a Texas Instruments plant that used 25 percent of the city's water supply, managed to reduce its water consumption by about 58 percent through the combination of an employee education program, recycling its process and cooling water, and developing a new ground water source (Levine 1982).

Public education and information programs designed to promote water conservation have been widely implemented throughout the United States--in some cases by state governments and, in others, by local municipal suppliers. In Florida, the Public Information Office of the South Florida Water Management District has become increasingly involved in preparing citizens for the implementation of the District's Water Shortage Plan. It has prepared a Water Shortage Information Service which includes two to four page fact sheets, each focusing on water resource issues or water saving hints. Examples of topics are "Supply-side Water Management," "In-Brief: The Water Shortage Plan," "Water Saving Devices: Faucets and Showers," "Changing Your Water Use Habits," and "Auditing Your Water Use." A water shortage logo has been developed and various media used to disseminate information and educate the public about the specific restrictions which are part of the plan--whether implemented on a voluntary or mandatory basis. In addition, television public service spots feature Florida's

Governor alerting residents and visitors to severe water shortages and urging them to become part of the "Florida Working Solution" (South Florida Water Management District 1982).

Many municipal water suppliers have purchased water-saving devices with municipal funds and distributed them in free conservation kits to domestic users, both as a public education and information strategy and as a way to ascertain the receptivity of residents to this kind of program. East Brunswick, New Jersey, undertook such a program, basing its appeal to the public primarily on the social and private economic benefits of conservation, since the city was not facing a drought or other water crisis which might have generated public support. The city experiment was judged successful, despite the non-crisis setting, with about two-thirds of the kits used (Palonini and Shelton 1982). A similar study was conducted in Oxnard, California (Morgan and Pelosi 1980) with about two-thirds of those receiving the kits actually installing at least part of the equipment; researchers attributed this high success rate to severe drought conditions in California and an intensive media campaign. However, the New Jersey experiment suggests that domestic users may be receptive to water conservation ideas regardless of current water conditions if adequately informed about benefits.

The Washington Suburban Sanitary Commission, a recognized leader in water conservation, has found public education effective in implementing a combined rate increase and individual water conservation program (Sharpe 1978b). Denver, Colorado, in the dry summer of 1977, used "a massive education effort" to acquaint Denver users with a new conservation program. All users were designated as squares, diamonds, or circles based on addresses. A "water calendar" was developed using these symbols to indicate appropriate days for outside watering. These were distributed to customers and inserted in newspapers with paid advertisements. Radio and TV stations used public service time and weather reports to alert people of the daily symbol from the calendar. The Denver Water Utility attributed the successful conservation effort to this education effort which enhanced customer understanding and cooperation; however, the program was mandatory and a fine system was used for violators (Miller 1978).

The Dallas, Texas Water Utility also described education and information as long-term tools of its water conservation program, with the primary value being suppplemental to more direct pricing measures such as heavy-demand surcharges (Rice and Shaw 1978). The East Bay Municipal Utility in the Oakland, California Area, has used public information to develop a water conservation ethic. Some of the strategies have included a direct-mail campaign on water conservation and gardening sent to single family residences with a history of high water conservation, the development of a classroom education program, a speaker's bureau, distribution of materials and brochures on its rationing program and on how to read a water meter, and preparation of television news clips and news releases (Larkin 1978). The State of Oklahoma has also developed a statewide classroom education packet and makes conservation posters and informational brochures and films available.

C. Advantages

Technical options such as retrofit with water-saving devices, reuse of wastewater, recycling of process water, improved irrigation methods, crop switching, all offer significant savings in water use and can reduce stress on high quality supplies needed for drinking water. The impact which this will have on ground water will depend on local patterns of use.

Irrigated agriculture accounts for the largest quantities of ground water withdrawn but does not necessarily consume all of it; to the degree that irrigation efficiencies are low, water that is not consumed or evaporated can serve to recharge some aquifers. However, where supplies are dwindling or water tables are lowered on a seasonal basis, improved water management practices by farmers can reduce the stress, saving water for other current or future uses. Additional benefits created by the use of improved irrigation techniques include reduced runoff of sediments, typically loaded with nutrients and pesticides; reduced concentration of salts, nutrients and pesticides in the soil where they can leach into the ground water; reduced energy consumption for pumping; improved insect and weed control; and, consequently, reduction in pesticide and herbicide applications (Lehr 1983).

Municipal water supply conservation through domestic and commercial cutbacks or reduction in use can save energy and money by reducing pumping, treatment, and distribution costs. It also could delay expansion of the city's treatment facilities or source of supply. Curbing per capita use also can preserve supplies for future growth and development (U.S. EPA 1979).

Educational programs for the public can be effective in achieving almost any water conservation goal--whether a crisis or non-crisis situation (Schuelein 1981). Such programs (typically well received by communities) have been successful in reducing water demands. Public education can increase community understanding of water availability and quality issues facing policymakers, leading to more creative solutions and less conflict over typically unpopular actions such as rate changes or increases. Such efforts can be particularly helpful in overcoming the conventional wisdom in the Southeast--since water is abundant, wasted water will be of no consequence.

D. Disadvantages

While conservation of water seems to be a positive solution which has great appeal, it is not entirely without drawbacks. Shifting water policy from development of new or additional supplies to management of demand through conservation may be difficult in the Southeast. The perceptions of the relative abundance of water in the region is widespread and is obviously correct in many areas. Moreover, major water users and interest groups such as farmers and industry are likely to believe that they have not been wasting water and may actually need more water rather than less (Weatherford 1980).

Conservation can be a multiple-goal program, used for seeking water use efficiency in one location and for protecting in-stream values in another. Thus, users will look cautiously at the trade-offs they are asked to make in supporting conservation programs. For example, a primary issue in conserving water is that public officials may use the water saved to encourage further growth and development of a local area, rather than taking advantage of an opportunity to reduce stresses on the ground water system.

Municipal suppliers are particularly wary of voluntary conservation because it places the initiative in the hands of consumers. Water managers may not want to depend on public education as an alternative tool to supply options or other demand options such as pricing, water pressure suppression and leak detection and repair. If conservation efforts are successful, consumers may reduce demand and keep demand at levels which will not give the utilities the revenue they need to cover operating and capital costs. Thus, conservation may result in increases in rates which will negate the initial economic incentives for conservation. Some studies indicate that conservation may drop off sharply after a certain level with diminishing results for continuing efforts. Lastly, the effectiveness of conservation strategies among rural users is somewhat harder to assess because of the lack of metering.

E. Feasibility

Technical conservation options have been adopted successfully across the United States in a variety of settings. Where water supply problems are severe, such as in California, Arizona, and Florida, state officials have had an easier time gaining acceptance of the idea of water conservation and developing a specific plan. In the Southeast, generally, conservation plans have played less of a role. Evidence suggests, however, that recent experi-ences with droughts can increase the likelihood of state or local action (New England River Basin Commission 1981).

Adoption of the conservation approach also may depend on whether it will be voluntary or mandatory. Community leaders and local interests, especially heavy water users, must be involved to ensure that the plans are workable. The existing institutional framework influences how readily conservation efforts can be adopted, especially in rural areas, where domestic users are often served by single wells without meters or other measures of use (Larson 1982). Many technical options for conservation are economically feasible. Public attitudes toward conservation and uncertainties about implementation are likely to present the largest constraints.

Public education programs to promote water conservation have been adopted throughout the United States both as a single and as a supplementary approach to reducing water demands. These programs, if well done, require expertise and financial resources to plan and develop and thus must compete for scarce money in states which frequently are hard pressed. Evidence also suggests that some water supply managers generally have negative attitudes toward conservation practices as a way to reduce demand (Sawyer and Petzold 1982; Science and Public Policy 1983). This may constrain the development of effective public education efforts. The support of local officials of water agencies or utilities as well as of professional groups such as plumbing engineers and cooperative extensions can be critical in developing public education efforts. Also, less is known about the public water use habits and attitudes of rural residents using individual wells as a primary source compared to municipal users. Thus, adopting a public education program for these people may require more research (Larkin 1982).

7.4.2 Pump Taxes

In addition to, and often used in conjunction with, the conservation practices discussed in the previous section, economic incentives are available to help manage the demand for water. Alternative pricing schedules can be used to affect water requirements of those served by city or municipal supply systems (see Section 7.4.3). For users who drill their own wells and provide their own source of supply, primarily rural users and some industries, pump taxes can be used as a mechanism to control demand. Pump taxes are fees paid for the use of ground water and are based on the amount of water pumped by the user.

Although the primary goal of a pump tax is to reduce demand and alleviate stress on the ground water system, they also can be used to promote more efficient use of the resource by allocating it to the most productive uses. By paying for water that previously was free (except for the cost of getting the water out of the ground and to the place of use), the self-supplied users may become more aware of just how much water is withdrawn and the amount of this water that is wasted. This could lead to the adoption of more efficient and water conserving practices; for example, agricultural users might switch from field flow or flooding irrigation to trickle or drip methods (see Section 7.4.1). Further, the end use of the pumped water might be shifted from livestock watering to irrigation if this was a more productive use.

The application of a pump tax to individual users could vary depending on the availability of adequate supplies to meet the level of demand and the water use priorities of a particular state or area. Pump taxes could be levied on all withdrawals by self-supplied users or could include exemptions for certain uses or sectors. For example, self-supplied industrial users might be excluded from paying pump taxes as an incentive to locate in that state. For some states, agricultural users may not be required to pay pump taxes because of the importance of that sector to the state's overall economy.

For those users who do pay pump taxes, the amount of water subject to taxation and the rate of tax could be constant or vary depending on the amount used and, perhaps, the end use. Pricing schedules could range from a flat rate tax to numerous sliding scales--e.g., the more you use, the greater the tax; the tax is imposed only on withdrawals above a certain amount. For a more complete discussion of alternative pricing options, see Section 7.4.3.

Three basic methods exist for determining the amount of water withdrawn. The most accurate method would be to tax the number of gallons withdrawn as measured by a wellhead meter. However, placing meters on all wells and developing the capacity to monitor the meters would be quite expensive. Less reliable, but also less costly, would be self-reported estimates made by the users. Without a way to cross-check the users' estimates, the incentive would exist to underestimate the amount of water used and the impact on demand reduction might be minimal.

A third alternative would be to use the amount of water that appears on a withdrawal permit as the base for calculating the pump tax. However, the amount permitted may not correspond to the actual amount pumped; a user who pumps less than the withdrawal permit allows will be paying for water not used. On the other hand, the incentive exists to request a low amount of withdrawal on the permit, pay taxes on this amount, and then to pump "free water" beyond the permitted amount. Although many of the states in the Southeast (North and South Carolina, Florida, Mississippi, Georgia, and Kentucky) already have some form of a permitting system that could serve as the basis for a pump tax, these are basically self-reporting systems and do not rely on meters for accurate measurement of the amount of water actually pumped. Further, none of these programs covers all ground water withdrawals; specific sectors (e.g., agriculture) are exempted or permits are required only for withdrawals greater than a certain amount (e.g., 50,000 gpd).

In 1980, Arizona enacted a state Ground Water Management Code which included management goals, a program for reducing ground water withdrawals, and a requirement for an assured water supply for new developments (see Section 9.3.1). In active management areas, withdrawals are controlled by the use of permits and meters on all nonexempt wells. The director of the Department of Water Resources has inspection and injunction powers to ensure compliance with the withdrawal restrictions. The code authorizes a pump tax or ground water withdrawal fee of not more than $5.00 per acre-foot. This revenue is used to support the administration of the state's ground water program, develop augmentation projects, and to purchase agricultural land in order to retire it from use, thereby reducing the strain on ground water resources (Kyl 1982b; Higdon and Thompson 1980; Pontius 1980).

The feasibility of controlling demand in the Southeast through the use of pump taxes is low at this time. Any self-reporting system is not likely to be effective in reducing demand. Even though permit systems are in place in some states, without metering and monitoring capabilities, using the permits as a basis for the pump taxes is not very functional. As noted previously, the use of individual well meters would require a large expenditure of time and money to implement. In addition, an institutional structure for administering such a program would need to be created.

Perhaps the greatest barrier to the use of pump taxes is the likely opposition from the rural and agricultural users--83 percent of the rural domestic and livestock water supply comes from ground water sources; 54 percent of the irrigation requirements in the Southeast is accounted for by ground water supplies (see Section 5.2.1). As noted by Hutchinson (1981), agriculture is a powerful force in the Southeast and many farmers believe that they own their land and their water and they can do with it what they please.

7.4.3 Pricing Alternatives

A. Description

Pricing water is one way to give individual users information about the supply of and demand for the resource in their area to help them make choices about the amount and types of uses they value. By determining the true value of water in specific locations and at specific times, water suppliers can use pricing to discourage excessive consumption of water and to induce development of water supplies. However, because water prices are typically set as a matter of policy rather than determined by market forces, public and private suppliers must incorporate as much information as possible about demand and cost changes over time, location, and groups of users in order to retain the efficiency aspect of pricing. Pricing policies may also incorporate public concern over the fairness of varying rate structures.

Most managers are faced with multiple goals, including generating sufficient revenue to cover costs, choosing prices which are efficient, meeting public demands for equity in rate structures, and promoting conservation of the water itself. Many pricing alternatives are available, each addressing one or more of these goals. Some of the most frequently discussed strategies are marginal cost pricing, seasonal rates, peak-load pricing, decreasing block rates, flat rates, lifeline rates, and conservation pricing.

Marginal cost pricing is based on the additional cost of producing or selling more or less water service. Two factors contribute to this price: short-run marginal cost is the change in cost caused by changes in uses of existing capacity; long-run marginal cost is the cost of expanding capacity and the change in operating costs associated with that new capacity. This approach, which uses projections of cost changes, contrasts with average cost pricing which is based on historical accounting costs (Davis and Hanke 1971; Mann and Schlenger 1982).

Seasonal pricing and peak-load pricing attempt to incorporate the dimension of time into either average or marginal cost calculations. In areas which experience significant variation in seasonal demands, usually high peaks during the summer months, seasonal pricing can be used specifically to reduce demand. Higher prices during peak demand periods accurately reflect the costs of greater capacity requirements, while lower prices during off-peak periods, usually winter months, reflect the fact that the water utility is operating at less than full capacity. Daily and even hourly fluctuations in demand can also be priced but these do not affect overall capacity of the system in the same way that sustained seasonal demands do and therefore are typically included in marginal cost estimates (Davis and Hanke 1971; Lippiatt and Weber 1982).

Decreasing block rates establish a price based on the volume used, with prices declining as the amount of water used increases. For example, customers might pay $2.00 per 1000 gallons per month (gpm) up to 6000 gpm and only $1.50 per 1000 gpm used in excess of 6000 gpm. These rates recognize the differing water use and costs of service for each of several major groups, including residential, commercial, and industrial users; they have been justified by the lower peak-to-average demand factor impacts on capacity by the larger users. Utilities typically modify this approach to attach a minimum service charge for very low volume users who would not be obligated to pay enough to the utility for it to recover the cost of water delivery (Ide 1980; Sawcheck 1981).

Flat rates establish a fixed fee for water service regardless of the amount of water consumed and are the typical approach used in areas without meters. Customers are charged an amount which generates sufficient revenues to cover the utility's basic operating and maintenance costs; this charge can be raised to cover investment obligations for expansion of supplies. This is different from a constant unit price in which the permit cost remains the same regardless of the total amount of water consumed (Ide 1980; Davis and Hanke 1971).

Lifeline rate structures are designed to ensure that every user can have a specified amount of water, usually enough to meet basic needs, at a price they can afford rather than at the real cost of the service. This is accomplished by charging large volume users more than low volume users per unit of water (Ide 180).

Conservation pricing strategies have the objective of reducing consumption. The constant unit price mentioned above can be interpreted as a conservation strategy in that it does not reward large users by giving them a break on rates. An inverted rate structure charges customers a higher price for each additional block of consumption, thereby penalizing them for increased consumption. A U-shaped rate structure uses the declining block rate approach up to a specified level before then moving to an increasing block rate. This accomodates moderately large users but heavily penalizes the largest users for extra capacity costs (Ide 1980).

These alternatives may be combined to generate an overall rate structure. For example, a flat service rate is often charged to cover administrative costs and combined with one of the unit rate structures to recover costs of operating, maintenance, and capital investments. Conservation pricing may be superimposed on the regular pricing structure during severe droughts (Lippiatt and Weber 1982).

B. Current Status

Studies of pricing policies in the United States have concluded that prices are almost never used primarily to control uses; that is, demand management through pricing is not a standard practice (Davis and Hanke 1971, 4). Rather, utilities continue to use large fixed and minimum charges based on average costs and concentrate on collecting operating revenues and rates of return sufficient to cover investments in new facilities (Davis and Hanke 1971; Lippiatt and Weber 1982). Traditionally, water managers have focused on projections of industrial and population growth to determine future needs and required supply capacity. This approach tended to underestimate the cost of water service, to result in overdevelopment of supplies, and to overlook important strategies for reducing demand such as leak detection and repair, education programs, and increased metering and changing prices (Davis and Hanke 1971; Comer and Beilock 1982).

However, utilities have begun to adopt pricing alternatives to affect consumer demand. The Washington Suburban Sanitary Commission in Maryland implemented an increased water rate schedule in 1978 as part of an overall conservation plan. The first two steps in the plan were a publicity and education program and the issuance and enforcement of a revised plumbing code. A citizen's study committee recommended that the Commission base its new rates on two principles: (1) customers making increased demands should be required to pay for the extra capacity required; and (2) the price structure should encourage all customers to conserve. The committee's specific pricing recommendation was to use an increasing rate schedule for water and sewer service and to eliminate summer surcharges and meter service charges. The commission conducted preliminary studies to determine the impacts of the proposal rate schedule on various types of users to judge particularly adverse or unintended effects, especially since it is prohibited by law from charging differential rates among customers. The rate structure adopted in January 1978 was based on 100 steps or 380 gallon per day increments. The water unit starts at a base average daily cost of 380 gpd and goes to 38,000 gpd or more. Rates associated with these units range from $0.36 to $1.05/1000 gpd. Initial evaluation of changes in demand in response to these rates show that commercial and governmental accounts showed a decline in water use of .03 percent; in contrast, residential customers had reduced water use by 13.8 percent by June 1978 (McGarry and Brusnighan 1979).

The Denver Water Department initiated a study of three alternative rate structures (spatially differentiated prices, peak-responsibility prices, and reverse block rates) as demand management management strategies and found that peak-responsibility pricing would be the most effective for achieving the objective of reduced water use. In this study, the capital costs of extra capacity were distributed throughout the year. The costs of treatment and storage based on a maximum use day were charged 37 percent to base costs and 63 percent to extra capacity costs. The operating costs (e.g., pumping, transmission, and distribution facilities) based on the maximum hour were charged 22 percent to base costs and 78 percent to extra capacity costs. The extra capacity costs then were distributed over a two or three month period with the base costs distributed over the entire year. In Denver, the climate and usage pattern result in a summer peak period and winter off-peak period. Denver has not yet implemented this pricing strategy. The city currently uses the declining block rate structure which is counter productive to its conservation needs. However, the city does not does not have meters for all its customers; as of 1976, over 50 percent of the homes served by the Denver Water Department were without meters (Zamora, Kneese, and Erickson 1981). The city has required meters on all new residences since the late 1950s and plans to meter those services built earlier; however, lack of financing for the meters has blocked the plans to date (Flach and Roussos 1978).

The use of a flat rate for unmetered services makes the participation of consumers in the conservation program less meaningful primarily because those customers do not see any savings in their flat-rate charge even though they have cut back the amount of water used and restricted their use to a three-hour per day period. Since this flat-rate is based on the size of the home and the number of toilet and bath facilities and water using appliances, there is no price incentive to use water efficiently (Miller 1978; Zamora, Kneese, and Erickson 1981).

Tucson, Arizona, the largest U.S. city wholly dependent on ground water for its water supply, has adopted a mixed pricing strategy designed to sharply curtail demand. Using recommendations from a citizen's advisory committee, Tucson's city council adopted a sizeable seasonal use price differential to account for high costs of service and help determine the true need for capital improvements to expand capacity. Tucson's average daily demand during the summer months is typically three times the average daily demand in the winter. Other recommendations adopted included increasing block rates for residences and small businesses in the summer with flat-rate summer charges for large businesses and industrial users. All classes were given flat-rates for winter. Although the committee voted against using lifeline rates, the city council adopted them in addition to the recommended rates. Tucson achieved its goal of 25 percent reduction in demand during the peak summer season of 1977, attributing the success both to prices and voluntary efforts apart from economic incentives. Since that time, the council has moved to an increasing block rate structure for winter and summer use to further affect demand (Zamora, Kneese, and Erickson 1981).

Many other cities across the United States have used pricing strategies to achieve reduction in demand. Dallas, Texas, used the surcharge pricing system to encourage conservation during a particularly dry period and reported demand reduction of about 12 percent (Rice and Shaw 1978). The East Bay Municipal Utility District in the San Francisco area of California also used the surcharge pricing system to achieve an overall 35 percent reduction in demand (Lottie and Vossbrink 1977; Harnett 1978).

C. Advantages

Water demand has been shown to be sensitive to changes in price. The level of sensitivity does vary among users, especially among types of users. Many large industrial users, for example, have relatively fixed water demands in contrast to residential and small business users who can vary both the level and time of use. However, in order to make informed choices about water use, customers benefit from prices which reflect as closely as possible the true production, transmission, and distribution costs of water, as well as the cost or savings of consuming or conserving additional increments of water.

Marginal cost pricing particularly provides consumers some information about the cost of their consumption decisions; without this information, they are likely to consume either too little or too much. Where water is scarce, the marginal price of supplying it will be higher than in locations where water is more easily accessed. Similarly, in dry seasons which coincide with heavier demands for outside uses, the cost of that additional capacity will make marginal prices higher. In these ways, marginal cost pricing gives customers information about the availability in that area and at that time (Davis and Hanke 1971).

As customers reduce demand in response to the new pricing, water managers may be able to delay costly expansion of facilities, especially where seasonal peak demand periods can be leveled off; sewage treatment facilities may experience reduced demand as well. Customers who are unable to reduce their demands will at least be paying rates which can finance the suppliers' capacity needs. The improved financial condition of the utility as well as the matching of costs to those most responsible for them can improve the public image of the utility (Mann and Schlenger 1982).

Heavy surcharges for excessive water use during droughts or peak periods have been demonstrated to be effective in curbing demand and appear to be accepted by the public as fair (Hill 1979). Pricing incentives have also been used to reward consumers who achieve significant reductions in consumption (Griffith 1978). Tax penalties or credits may be particularly useful in areas which have already achieved a moderate improvement in demand reductions and want to push for additional savings under emergency conditions such as droughts or contamination incidents.

Lifeline rates address social concerns over particular groups of customers or types of service. By providing a subsidy to low income users or essential services such as hospitals, lifeline rates assure that community values are addressed, often without undue distortion of prices to other users. They are popular politically, as in the case of Tucson where the city council implemented them despite a contrary recommendation from its citizens' advisory committee (Zamora, Kneese, and Erickson 1981; Ide 1980).

Pricing water to improve its efficient allocation has been described as very difficult to accomplish, and problems do exist in applying some economic principles to water rates (see Disadvantages below). However, close estimates or "best guesses" of marginal costs can be made in the same way that the current cost studies are made. The experiences to date of utilities implementing price strategies designed to reduce demand appear to be successful, especially where these changes in rates were accompanied by public participation or education programs and some consideration of principles of fairness and simplicity in the rate design (Mann and Schlenger 1982; Renshaw 1981; Ide 1980).

D. Disadvantages

Controversy continues among cost analysts regarding the most appropriate pricing strategy and rates for affecting demand and the actual magnitude of these effects. This reflects, in part, the complexity and uncertainty involved in moving from economic theory and models about water demand functions to application under varying conditions and types of users (Howe 1982; Mann and Schlenger 1982). Economic theory suggests that water, like other commodities or output, should be priced at marginal cost. In practice, however, this may be constrained both because of the difficulty and cost of getting needed information about public preferences for protection of social or aesthetic values and because of disapproval of utilities carrying profits over time (Zamora, Kneese, and Erickson 1981).

Specific problems caused by the lack of reliable data on the price elasticity of water during heavy demand periods include the uncertain effects on revenue collections and load, operating, and capacity needs. The tendency of marginal cost pricing to produce excess revenues at times can create a problem for utilities primarily because methods used to redistribute the revenues, such as adjusting marginal rates, tend to be arbitrary, lack a theoretical base, and produce incorrect price signals (Mann and Schlenger 1982). Nonetheless, marginal cost pricing may be preferable to average cost pricing which has tended to collect insufficient revenues (see Advantages above).

Marginal cost pricing assumes that the resulting allocation of water through costing is reasonable and equitable. However, such a pricing strategy may place unacceptable burdens on low income users or on large commercial users in an area. In such cases, the utility may want to consider lifeline rates at the lowest end of the rate schedule and flat rates or constant unit pricing at the upper extremes of the schedule.

Anticipated economic efficiency may not occur under marginal cost pricing if a water utility is mismanaging its resources by failing to minimize costs. Improved efficiency also may not result if other sectors of the economy are not priced efficiently. For example, substitutes for water supplies such as bottled water, inputs used in producing water such as treatment chemicals, and appliances using water theoretically should all be priced at marginal cost in order for water service to achieve economic efficiency. However, empirical studies have not demonstrated that, in the absence of such perfect conditions, marginal cost pricing would distort resource allocation more than other types of rates (Mann and Schlenger 1982).

Seasonal peak-load pricing may also produce unintended or uncontrollable effects on demand. While customers may reduce overall or average demand for water during moderately dry seasons, they may not be able to get by without watering during extremely dry days. This indicates a situation in which there are short periods of heavy demand requiring excess capacity, despite overall reduction in demand. The seasonal peak also may simply shift or "wander" to another time period without a decrease in size. This results when consumers get delayed feedback through the billing cycle and then slowly adjust their use (Mann and Schlenger 1982).

Pricing strategies do require meters, timely reading of those meters, and feedback in the form of bills. Many cities in the United States, and particularly in the Southeast where water abundance has made the need for meters less pressing, have no meters or large portions of their residential accounts unmetered. In these areas, pricing as a demand management strategy is simply not a viable option since there is no way to provide the customer with information about the amount and cost of the water used. Utilities can estimate the cost of meter installations and either raise monthly charges over a period of time to cover the costs or persuade the public to purchase them directly. In water abundant areas, the costs of meter installations, however, have been judged to outweigh the costs of expanding supplies.

Related to meters is the problem of timely meter reading and billing cycles. Monthly reading and billing is the typical performance by utilities; some do this quarterly. By delaying the information given to the consumers about their water use patterns and the cost of their demand, the utility causes a delay in the behaviorial changes needed. Utilities can work to counteract this problem by using public information campaigns to alert customers to current water supply conditions, teach and encourage them to check their own meters to be sure they are within their own plan for use, and provide information clearly on bills about total water use and how it compares with average demands of like customers (Griffith 1982; Mann and Schlenger 1982; Zamor, Kneese, and Erikcson 1981).

Changes in pricing, especially in the typical case of price increases, can create adverse public reaction, leading to loss of large industrial customers whose demands are constant, unpaid accounts by low-income users, or the drilling of wells for individual water supplies. Customers as well as water managers often prefer the status quo and, thus, find any major change risky and difficult. Water managers may prefer, for example, to increase supplies in response to increased demand rather than using prices to achieve optimum allocation for several reasons, including the fear of revenue losses from new rate structures, the perceived abundance of water, and the belief that conservation-oriented alternatives are not popular with the public (Sawyer and Petzold 1982; Griffith 1982; Mann and Schlenger 1982; Ide 1980). The public may also want aesthetic values protected, including instream uses for wildlife. These values can be accomodated through a reduction in demand, but they are difficult to incorporate in pricing schemes (Robie 1974).

E. Feasibility

Many difficulties are involved in implementing new or varying pricing strategies to affect demand for water. Available data for projecting costs or demand elasticity may be inadequate or unavailable. Public values of equity may not coincide with the optimum rate schedule. Revenues may be unstable initially as customers respond to the new cost information on their bills. Lack of meters may constrain use of pricing for a particular utility or group of customers.

However, marginal cost and seasonal pricing strategies have the distinct advantages of moving a utility toward more economic efficiency and sending customers correct information about the value of using or conserving more or less water. Most of the barriers to improved pricing can be mitigated. Public acceptance is greatly facilitated by public education programs. Equity concerns can be addressed through a mix of rate schedules. Tax incentives or penalties can be used in areas which have already achieved significant reductions in demand. Utilities using improved pricing schedules to achieve some control over demand have generally been successful; however, those combining new rate schedules with other programs such as public education and installation of water-saving plumbing devices have achieved greater success during the initial implementation phase.

Increasing rates gradually also can reduce public opposition. Since future costs of supplying water will be high, water utilities need to assess current conditions and demand patterns in their service area and develop pricing alternatives which address their particular situations. In areas where competition for water resources continues to increase, utilities will have to increase rates in the future. If experiences in areas such as Dallas, Washington, D.C., and Tucson are indicative, the chances of getting those rates accepted increase substantially with planning and complementary programs.

7.5 SUMMARY

This chapter has discussed options for dealing with problems encountered when attempting to ensure that adequate water supplies are available to meet the demands. Included were alternatives for addressing the shortcoming of the legal and institutional systems that regulate water resources, structural options for increasing the amount of water available for use, and techniques and strategies intended to control the demand for water.

Regardless of whether a state favors creating a market-like allocation system or one characterized by tight, central control, a key concern for states is how to structure water rights in order to improve water allocation. Most states in the Southeast already have rejected a complete prior appropriation system and have adopted aspects of a permitting system. In areas where water is still relatively abundant and few conflicts exist among users, states may be best served by clarifying the parameters of water rights including liability and transfer issues, and through statutory modifications; further clarification of the allocation mechanisms could still be made through case by case litigation.

Most states, however, have at least some areas which are water short because of heavy demands, lack of proximate supplies, or because of the poor quality of the local water; in these instances, the state has the responsibility to intervene directly in the allocation process. States already have taken steps in this direction by establishing permitting systems which provide authority for imposition of use restrictions in areas of particular concern.

These systems as adopted in the Southeast generally are very flexible and few are strictly enforced. States can develop more comprehensive systems by eliminating exceptions for specific consumer groups and by developing more specific criteria or guidelines for choosing among applicants for water rights. Although this reduces the discretion of state and local administrators, it also can strengthen the security of rights, thus making investments in the development of water resources more attractive. Permit systems also can provide protection of the public interest in environmental concerns--interests which are difficult to incorporate in the more market-oriented approach or common law doctrine allocation.

Modifications to existing water laws to develop a more comprehensive water resources management system provides the context within which action can be taken to ensure adequate supplies--whether through the increased use of surface water or through ground water augmentation. The actual option(s) adopted depends on local variation in the purpose of increasing water supplies, the political context, hydrogeologic characteristics, and cost. For example, if the intent of a recharge project is to stop saltwater intrusion or reduce land subsidence, recharge water would not necessarily need to meet high quality standards. If the purpose is to recharge an aquifer used as a source of potable supplies, recharge water may require costly treatment prior to use in the project. However, in some areas the cost of treating water to be used for aquifer recharge still may be less than the cost, for example, of transporting water from a distant surface source.

Political factors also can play an important role in selecting among supply alternatives. Although the technology is available for transporting water over long distances, water transfer projects might not be acceptable because of the political and legal problems of diverting water from one political or administrative jurisdiction to another. In the same geographic area, artificial recharge by surface spreading also may be rejected as a viable option because developers often resist attempts to set aside the large amounts of land required for this method of recharge. On the other hand, direct injection of excess water during wet seasons into a nonpotable aquifer for storage and use at a later time might be an acceptable alternative.

Thus, although the technologies are available that would enable the structural options in this chapter to be used, it is not possible to say one option is better than another without considering each option in the context in which it would be implemented. The most important factors for a particular area or situation need to be defined and the trade-offs among the options considered in light of these factors. Further, in practice, no single option is likely to be adequate if water supply needs are severe. The decision may not be which option to use but rather, in what combination should the supply options be used and how do these options fit with the other components--water allocation strategies and conservation--of an overall water supply management system.

Even if more water can be made available for use in some areas, water requirements to meet the demands resulting from rapid growth development could still exceed the available supplies. In these instances and when supplies are short because of seasonal dry periods or extended drought, options are required that will help control the demand for water. Water managers (e.g., municipal suppliers) traditionally assumed that water use is insensitive to conservation efforts and price changes and, therefore, focused on water requirements as a basis for management. Water needs have been determined by using population projections and per capita or average water use estimates; conservation and pricing were seldom included as part of the management plan.

The availability of financing and technical assistance from the federal government for development of supplies (particularly surface water) also favored water management decisions that focused on development projects. At the same time, conservation and pricing options typically have been viewed as a response to unanticipated shortages rather than as long-range alternatives to manage supplies more efficiently. Yet these options are clearly viable, even in areas with generally abundant supplies, if combined with programs to educate and inform the public about the benefits they can generate.

In general, the states in the Southeast have extensive ground water systems and an abundance of lakes, rivers, and streams as sources of supply to meet water needs. The problems associated with providing an adequate supply or that result from overpumping of ground water resources are localized in nature but can be quite severe. The options discussed in this chapter are intended to help alleviate these local problems and be used as part of an overall water management system. These options have some potential for providing more supplies or reducing demand, but none alone will solve the problems of shortages or provide a firm basis for future growth and development. Alternatives for providing adequate supplies need to be implemented in conjunction with options for controlling the demand for water and both sets of options need to be part of a comprehensive water management system that is guided by a well-developed institutional framework.

REFERENCES

Asano, Takashi, and Kurt L. Wassermann. 1980. "Groundwater Recharge Operations in California." American Water Works Association Journal 72 (July): 380-85.

Atlanta Regional Commission. 1980. Reduction in Routine Water Demand Through Water Conservation. Metropolitan Atlanta Water Resource Study. Atlanta, GA: The Commission.

Ballard, Steven C., and Michael D. Devine, et al. . 1982. Water and Western Energy: Impacts, Issues, and Choices. Boulder, CO: Westview Press.

Bell, Frank A. 1981. "Protocol Development for Potable Reuse Criteria and Standards." In Water Reuse--An Alternative in Water Resources Management, edited by William J. Cooper, 52-59. Miami: Florida International University, Drinking Water Research Center.

Bennett, Truman. 1982. "Shades of Immortality: Where Do We Hang The Plaque?" Ground Water 20: 390-92.

Brown, D. L., and W. D. Silvey. 1973. "Underground Storage and Retrieval of Fresh Water from a Brackish-Water Aquifer." In Second International Symposium on Underground Waste Management and Artificial Recharge, New Orleans, September 26-30, 370-419.

Brown, Ernest C., and Nathaniel Weinstock. 1981. "Legal Issues in Implementing Water Reuse in California." Ecology Law Quarterly 9: 243-94.

Cederstrom, D. J. 1957. Geology and Groundwater Resources of the York-James Peninsula, Virginia. U.S. Geological Survey Water Supply Paper 1361. Alexandria, VA: U.S. Geological Survey

Clean Water Act of 1977. Pub. L. 95-217. 92 Stat. 1566.

Comer, Dorothy, and Richard Beilock. 1982. "How Rate Stuctures and Elasticities Affect Water Consumption." American Water Works Association Journal 74 (June): 285-87.

The Conservation Foundation. 1982. State of the Environment 1982. Washington, DC: The Conservation Foundation.

Cox, William E. 1982. "Water Law Primer." *Proceedings of American Society of Civil Engineers* 108 (March): 107-22.

Cox, William E., and Leonard A. Shabman. 1980. "Water Supply in Virginia: Toward a Definition of Management Issues and Options." In *Land: Issues and Problems*. Virginia Cooperative Extension Service, 54 (June-December).

Culp, Westner, Culp. 1979. *Water Reuse and Recycling: Vol. 1, Evaluation of Needs and Potential*. Washington, DC: Department of Interior, Office of Water Research and Technology.

Dewsnup, Richard, and Dallin W. Jensen. 1973. *A Summary-Digest of State Water Laws*. Washington, DC: Government Printing Office.

Davis, Robert K., and Steve H. Hanke. 1971. *Pricing and Efficiency in Water Resource Management*. NWR-SBS-72-044. Springfield, VA: National Technical Information Service.

Fisher. 1958. "Western Experience and Eastern Appropriaton Proposals." In *The Law of Water Allocation in the Eastern United States*, edited by Haber and Bergen, 75-79.

Flack, J. Ernest, and George J. Roussos. 1978. "Water Consumption Under Peak-Responsibility Pricing." *American Water Works Association Journal* 70 (March): 121-26.

Geraghty, James J., et al. 1973. *Water Atlas of the United States*. Syosset, NY: Water Information Center.

Griffith, E. 1978. "Southern California's Drought Response Program." *American Water Works Association Journal* 70 (February): 74-78.

Griffith, Fred P., Jr. 1982. "Policing Demand Through Pricing." *American Water Works Association Journal* 74 (June): 288-91.

Harnett, J. S. 1978. "Effects of the California Drought on the East Bay Municipal Utility District." *American Water Works Association Journal* 70 (February): 69.

Heath, Milton S., Jr. 1978. "Some Current Legal Issues in North Carolina Concerning Diversion of Water for Public Water Supplies and Related Matters." In *Legal and Administrative Systems for Water Allocation and Management: Proceedings of a Southeast Regional Conference*, edited by William E. Cox, 168-93. Blacksburg: Virginia Polytechnic Institute and State University, Virginia Water Resource Research Center.

Higdon, Philip R., and Terence W. Thompson. 1980. "The 1980 Arizona Ground Water Management Code." Arizona State Law Journal 621-67.

Hill, G. 1979. "Stiff Curb Favored in Saving Water." New York Times, (March 4).

Howe, Charles W. 1982. "The Impact of Residential Water Demand: Some New Insights." Water Resources Research 18 (August): 713-16.

Hutchinson, Bill. 1981. "Running on Empty." New Florida (October).

Ide, William J. 1980. "Designing Equitable Water Rates: What Managers Need to Know." American Water Works Association Journal 72 (October): 564-69.

Johnson, Dale. 1982. U.S. Geological Survey, Myrtle Beach Field Office. Personal communication, June.

Kemp, Deborah J. 1982. "Interbasin Transfers of Water in Florida." The Florida Bar Journal 56 (January): 9-21.

Kincannon, D. F., and W. G. Tiederman. 1972. Water Reclamation for Ground Water Recharge, July 1971-June 1972: Final Report. Stillwater: Oklahoma State University.

Kingston, W. L. 1979. "A Do-It-Yourself Leak Survey Benefit-Cost Study." American Water Works Association Journal 71 (February): 71-72.

Kundell, James E. 1978. Ground Water Resources of Georgia. Athens: University of Georgia, Institute of Government.

______. 1980. Georgia Water Resources: Issues and Options. Athens: University of Georgia, Institute of Government.

______. 1983. Science and Technology Associate, Institute of Government, University of Georgia, Athens. Letter, March 22.

Kyl, Jon L. 1982a. Comments at Ground Water Workshop, University of Oklahoma, Norman, October 27-28.

______. 1982b. "The 1980 Arizona Ground Water Management Act: From Inception to Current Constitutional Challenge." University of Colorado Law Review 53 (3): 471-504.

Larkin, Donald G. 1978. "The Economics of Water Conservation." American Water Works Association Journal 70 (September): 470-74.

Manwaring, James F., and Richard D. Heaton. 1981. "Reuse Overview." In Water Reuse--An Alternative in Water Resources Management, edited by William J. Cooper, 1-19. Miami: Florida International University, Drinking Water Research Center.

McGarry, Robert S., and John M. Brusnighan. 1979. "Increasing Water and Sewer Rate Schedules: A Tool for Conservation." American Water Works Association Journal 71 (September): 474-79.

McWhorter, D. B., and J. A. Brookman. 1972. "Pit Recharge Influenced by Subsurface Spreading." Ground Water 10: 6-11.

Miller, W. H. 1978. "Mandatory Water Conservation and Tap Allocations in Denver, Colorado." American Water Works Association Journal 70 (February): 60-63.

Morgan, W. Douglas, and Peter Pelosi. 1980. "The Effects of Water Conservation Kits on Water Use." American Water Works Association Journal 72 (March): 131-33.

Moulder, E. A., and D. R. Frazor. 1957. Artificial Recharge Experiments at McDonald Well Field, Amarillo, Texas. Texas Board of Water Engineers Bulletin 5701.

New England River Basins Commission. 1981. Before the Well Runs Dry: A Handbook for Designing a Local Water Conservaton Plan. Washington, DC: Federal Emergency Management Agency.

North Carolina Department of Natural Resources and Community Development. 1982. Jordan Lake Water Supply. Raleigh: Cape Fear River Basin Study Staff, Office of Water Resources.

Oeltjen, Jarret C., and Lloyd K. Fischer. 1978. "Allocation of Rights to Water: References, Priorities and the Role of Market." Nebraska Law Review 57 (2): 245-82.

Palonini, Dennis J., and Theodore B. Shelton. 1982. "Residential Water Conservation in a Noncrisis Setting: Results of a New Jersey Experiment." Water Resources Research 18: 697-704.

Pontius, Dale. 1981. "Ground Water Management: A New Set of Rules." Arizona Bar Journal 16: 28-52.

Putt, Larry O'Neill. 1978. "Alabama Water Law." In Legal and Administrative Systems for Water Allocation and Management: Proceedings of a Southeast Regional Conference, edited by William E. Cox, 2-8. Blacksburg: Virginia Polytechnic Institute and State University, Virginia Water Resource Research Center.

______. 1981. "An Analysis and Evaluation of Water Rights in Alabama in Perspective with Other States in the South Atlantic and Gulf Region." Cumberland Law Review 12: 92-97.

Reinhold, Roeber. 1982. "Houston's Great Thirst is Sucking Down into the Ground." New York Times (September 26): 19.

Renshaw, Edward. 1982. "Conserving Water Through Pricing." American Water Works Association Journal 74 (January): 2-5.

Rhode, Cy. 1983. Mississippi Chapter, Sierra Club. Letter, April 11.

Rice, I. M., and L. G. Shaw. 1978. "Water Conservation--A Practical Approach." American Water Works Association Journal 70 (January): 480-82.

Roberts, Paul V. 1980. "Water Reuse for Groundwater Recharge: An Overview." American Water Works Association Journal 72 (July): 375-79.

Robie, Ronald B. 1974. "Modernizing State Water Rights Laws: Some Suggestions for New Directions." Utah Law Review (Winter): 760-84.

______. 1982. Keynote Address, Oklahoma Governor's Water Conference, Oklahoma City, December 7.

Sawchuck, L. 1981. "Declining Block Rates Can Encourage Water Conservation." American Water Works Association Journal 73 (January): 13.

Sawyer, Stephen W., and Donald E. Petzold. 1982. "Water Conservation: Perceptions of the Need for It in a Water Rich State." Paper presented at the annual meeting of the Association of American Geographers, San Antonio, TX.

Schmidt, Curtis J., Ernest V. Clements III, and Stephen P. Shelton. 1978. "A Survey of Practices and Regulations for Reuse of Water by Groundwater Recharge." American Water Works Association Journal 70 (March): 140-47.

Schuelein, James W. 1981. Public Water Supply Conservation Guide. Publication no. 106. Oklahoma City: Oklahoma Water Resources Board.

Science and Public Policy Program. 1983. Southern Regional Environmental Assessment: Environmental Status Report. Washington, DC: Envirnmental Protection Agency. Office of Research and Development.

Sharpe, W. E. 1978a. "Selection of Water Conservation Devices for Installation in New or Existing Dwellings." In *Proceedings, National Conference on Water Conservation and Municipal Wastewater Flow Reduction*, Chicago, IL, November 28-29.

______. 1978b. "Why Consider Water Conservation." *American Water Works Association Journal* 70 (9): 475-79.

Shepherd, A. D., et al. 1980. *State Water Use and Socioeconomic Data Relating to the Second National Water Assessment*. ORNL Report TM7242. Oak Ridge, TN: Oak Ridge National Laboratory.

Shrew, D. Craig, and William J. Dunlap. 1981. "Organic Pollution of Ground Water: Its Prevalence, Implication and Control." In *Ground Water Management: Proceedings of a Southeast Regional Conference*, edited by James C. Warman, 164-84. Auburn, AL: Auburn University, Water Resources Research Institute.

Simpson, C. Leon. 1978. "Well-Field Management." *American Water Works Association Journal* 70 (March): 151-52.

Snipes, Edward. 1983. Southwest Florida Water Management District. Personal communication, June 27.

South Carolina. 1969. *Groundwater Use Act of 1969*. South Carolina Statutes, §49-5-10 through §49-5-120.

South Carolina Water Law Review Commission. 1982. *Report and Recommendations*. Columbia, SC: The Commission, December.

South Florida Water Management District (SFWMD). 1977. *Water Use and Supply Development Plan*. Vol. 3A, Lower East Coast Planning Area. West Palm Beach, FL: The District.

South Florida Water Management District. 1982. *Water Management Bulletin* (Winter) 7.

Spigner, B. C., Ken Stevens, and W. C. Moser. 1977. *Report on the Ground Water Resources of Horry and Georgetown Counties, South Carolina; A Ground Water Capacity-Use Investigation*. Report Number 129. Columbia: South Carolina Water Resources Commission.

Stallworth, Hank. 1982. Staff, South Carolina House of Representatives. Personal communication, June.

Stone, Brian G. 1978. "Suppression of Water Use by Physical Methods." *American Water Works Association Journal* 70 (September): 483-86.

Sullivan, Glenn. 1982. Remarks, Oklahoma Governor's Water Conference, Oklahoma City, December 7.

Todd, David Keith. 1980. Groundwater Hydrology, 2nd ed. New York: John Wiley & Sons.

Treadway, Dwight M. 1980. "Agricultural Water Use: Overview." In Georgia Water Resources, edited by James E. Kundell, 48-54. Athens: University of Georgia, Institute of Government.

Trelease, Frank. 1974. "The Model Water Code, the Wise Administrator and the Goddam Bureaucrat." Natural Resources Journal 14 (April): 207-29.

U.S. Department of Commerce. Bureau of Economic Analysis (BEA). 1980. Regional Economic Projections. Washington, DC: Bureau of Economic Analysis.

U.S. Department of Interior. 1979. Irrigation Water Use and Management. By an Interagency Task Force on Irrigation Efficiency, with the U.S. Dept. of Agriculture and the U.S. Environmental Protection Agency. Washington, DC: Government Printing Office, June.

U.S. Environmental Protection Agency (EPA). Region IV. 1978. Southeast Environmental Profiles, 1977. Atlanta, GA: U.S. Environmental Protection Agency.

______. 1979. Water Supply--Wastewater Treatment Coordination Study, Contract No. 8-01-5033: Public Comment and Review Draft, August. Washington, DC: Environmental Protection Agency.

______. Office of Water Supply and Office of Solid Waste Management Programs. 1979. The Report to Congress--Waste Disposal Practices and Their Effects on Ground Water. Washington, DC: Environmental Protection Agency.

U.S. National Water Commission. 1973. Water Policies for the Future: Final Report to the President and to the Congress of the United States. Washington, DC: Government Printing Office.

U.S. Water Resources Council (WRC). 1978. The Nation's Water Resources 1975-2000. Second National Water Assessment. Washington, DC: Government Printing Office.

______. 1981. State of the States: Water Resource Planning and Management; Ground Water Supplement. Washington, DC: Water Resources Council.

VanArman, Joel. 1979. "A Water Use Plan for the Lower West Coast of Florida--Progress Review." In-Depth Report (South Florida Water Management District) 4 (April): 1-16.

Weinberger. 1978. "Industrial Water Reuse." In Planning for Water Reuse, edited by D. Baumann and D. Dworkin. Cited in Ernest C. Brown and Nathaniel Weinstock, "Legal Issues in Water Reuse in California." Ecology Law Quarterly 9: 243-94, note 29.

Weatherford, Gary D. 1980. "Introduction: Western Water Management and the Conservation-and-Transfer Strategy." In Western Water Institutions in a Changing Environment, Vol. 1, by John Muir Institute. Napa, CA: John Muir Institute.

Wilson, Leonard U. 1978. State Water Policy Issues. Lexington, KY: Council of State Governments.

Work, Stephen W., Michael R. Rothberg, and Kenneth J. Miller. 1980. "Denver's Potable Reuse Project: Pathway to Public Acceptance." American Water Works Association Journal 72 (August): 435-40.

Zamora, Jennifer, Allen V. Kneese, and Eric Erickson. 1981. "Pricing Urban Water: Theory and Practice in Three Southwestern Cities." The Southwestern Review of Management and Economics 1 (Spring): 89-113.

CHAPTER 8

LAND USE MANAGEMENT

8.1 INTRODUCTION

Ground water problems are frequently related to the present or the past use of land. As discussed in chapters 3, 4, and 5 land users affect the ground water resource by withdrawing water or by allowing substances from their activities to enter the subsurface environment. Ground water users are frequently sensitive to these changes. As with many environmental and resource problems, management of the conflicts between land and resource users is often particularly difficult because the problems are created by the combined effects of many independent land use decisions or because ground water impacts caused by one land user are felt by adjacent or distant land users. As a consequence of these interrelationships between ground water and land use, several options for solving ground water problems fall under the general category of better management of land use.

The land use management options described in this chapter include a wide variety of generic techniques, such as zoning or land use planning, that can be used as part of a ground water management program. Modifications to each generic technique can be made with differing feasibility and effectiveness, in order to meet specific ground water management objectives. The variety of potential modifications complicates the description and evaluation of the techniques. As a result, discussion of land use management techniques in subsequent sections must be very general.

Land use management can serve two broad objectives. First, management can help prevent the land users from producing unacceptable changes in ground water or help them reverse past changes. Land users that adversely affect ground water can be discouraged from locating in sensitive areas or can be subjected to standards that mitigate their impact. For example, feedlots can be prohibited from recharge areas or septic systems can be subjected to design standards that reduce their potential to pollute.

Second, in areas with existing or potential ground water problems, land users that would be adversely affected by low ground water availability or poor quality may be restricted to minimize incompatible uses. For example, residences dependent on shallow wells tapping water table aquifers may be discouraged near industrial areas, landfills, or other potentially polluting land uses. Alternately, construction standards for residential wells can require minimum well depths, minimum casing depths, and minimum distances from septic drain fields; they may be implemented through land use regulations to protect rural or suburban population.

Land use management can help resolve either availability or quality problems. To prevent ground water availability problems, land use management can help to protect the quantity of aquifer recharge. For example, surface modifications that adversely affect runoff and infiltration can be prohibited through construction and use standards. The recharge capacity of wetlands, flood plains, and stream beds can be preserved by prohibition of certain kinds of development. Minimum lot sizes, design standards, use restrictions, and siting procedures can help to ensure appropriate well spacing and depths in order to prevent interference between wells and to protect certain priority users, such as municipal and private shallow wells. Finally, a variety of land use management tools can protect both aquifers and ground water users by restricting the location of users requiring large withdrawals, especially in areas of overpumping, salt water intrusion, or near possible pollution plumes.

To prevent ground water quality problems, land use management can protect the quality of recharge by (1) preventing the location of land uses with a high risk of ground water pollution in aquifer recharge areas, (2) by implementing performance or technological controls on hazardous land uses in recharge zones, or (3) by regulating the concentration of the pollution load discharged to ground water through lot size or other constraints on the density of discharges. Similar controls could also protect existing and projected wells and their users, but in this case the management focus would shift to ensuring sufficient hydrologic distance between discharges and wells to permit adequate attenuation of pollution. Regulations that require minimum distances between residential wells and septic drain fields are examples. Finally, land use management can restrict the location of land uses sensitive to water quality in areas likely to experience water quality problems, to require public disclosure of likely problems, or to require alternative water supplies.

This chapter discusses three categories of public land use management techniques (Table 8-1): (1) land use planning and information; (2) a variety of land use controls; and (3) siting procedures for particularly hazardous facilities other than hazardous waste disposal facilities.[1] Each could be used by state or local governments, alone or in combination with other land use or ground water

---

[1] See sections 6.5.3 and 6.5.4 for an analysis of siting programs for hazardous waste management facilities.

TABLE 8-1: LAND USE OPTIONS

Approach	Specific Option
8.2 Planning	1. Comprehensive land use planning 2. Land use information
8.3 Land use controls	3. Zoning 4. Performance standards 5. Purchase of land or land rights 6. Financial incentives 7. Development and construction design standards 8. Ground water classification based on land use standards
8.4 Siting controls	9. Siting procedures for high risk facilities

management options. Indeed, most of the existing effective public land use management programs combine a variety of controls (Gleeson et al. 1975).

8.2 LAND USE PLANNING AND INFORMATION

Planning is the process of gathering information and devising alternatives for rational decisions about the future. In combination with the larger policy process, planning involves (1) the identification of problems, goals, and/or objectives; (2) the collection and analysis of information; (3) devising alternative actions and combinations of actions (plans); (4) choosing a plan; (5) implementing the plan; and (6) monitoring results. The planning process is continous--new problems and objectives are constantly being identified. Many of these activities--such as choosing and implementing courses of action-often are not carried out by planning agencies; rather these agencies typically supply information, choices, and advice to decisionmakers. However, if the decisionmaking authority and planning functions are not closely integrated, the planning process is not likely to be effective.

This section addresses comprehensive land use planning and information. The first section describes integrating ground water management in comprehensive land use planning. The second section addresses the importance of land use information either as one part of the land use planning process or as an important data base for other ground water management approaches, such as the aquifer classification systems or permit programs described in Chapter 6.

8.2.1 Comprehensive Land Use Planning

A. Description

Land use planning has traditionally been exercised at the local level and has concentrated on socio-economic concerns. Implementation is primarily through zoning decisions. Until recently broader environmental and natural resources planning at the state and local level has been neglected, particularly for "invisible" resources such as ground water. Local planning also has tended to be geographically restricted in scope, with regional needs and impacts seldom considered. In the Southeast, where potential solutions may depend on state level decisions, local planning and land use controls may be a barrier to resolving ground water problems.

State, rather than local control may be required for many ground water problems which go beyond local boundaries or are statewide. More comprehensive land use planning programs have the advantage of including a wide range of concerns besides ground water. Statewide comprehensive land use planning, with its broader areal scope, would have the capacity to utilize more extensive information and provide direction for land use and development better fitting state or regional interests.

B. Current Status

In many areas of the U.S. there has been a trend toward shifting responsibility for land use planning and development control to the state, due in large part to growing environmental concerns (Mandelker and Cunningham 1979). A number of states, including Florida, Vermont, and Oregon, have implemented statewide programs of comprehensive land use planning and control that make explicit provision for resource, environmental, and regional or statewide concerns (Popper 1981). California, Maryland, New York, and Pennsylvania have less comprehensive programs that include state and regional interests for certain large projects or for fragile areas, some having ground water implications (Popper 1981).

Policy priorities of the federal government have both encouraged and fragmented state and local land use planning programs. The limited- or single-purpose nature of many federal programs, and lack of coordination among them, has resulted in fragmented programs at the state level. Examples include plans for housing, rural assistance, highways, and other federally sponsored activities. Ground water is only marginally of direct concern in any of these programs, with the result that land use plans under these programs rarely deal effectively with ground water. Although federal legislation for comprehensive land use planning does not now exist, it has been proposed. Some federal legislation and programs have encouraged more comprehensive state and local land use planning for certain sensitive lands, such as flood plains, the coastal zone, wetlands, and wild and scenic rivers.[1] These sensitive lands are frequently also important to ground water management.

Although planning pertaining to both ground water and land use is carried out at the state level in the Southeast, only in Florida could these efforts be termed comprehensive land use planning. Mushkatel and Judd (1981) noted that "governments historically have been reluctant to push the 'social responsibility' side of land use at the expense of the autonomy and freedom of private entrepreneurs". Governmental intervention in private land use decisions is frequently opposed in the Southeast, particularly at the state government level.

C. Advantages

Devising consistent, long range policy could be greatly aided by state comprehensive land use planning. Comprehensive planning infers that a broad range of goals and concerns is considered (e.g., economic, health and safety, resource management, living standards). This integration of goals can minimize conflicts encountered when narrow topics are addressed individually. Planning at the state level has a broader perspective than local or voluntary regional planning; negative impacts of localities upon one another can be minimized, and land uses with regional implications can be addressed. Economies of scale in the planning process may make continued financial support of planning less costly and therefore less susceptible to the fluctuations of public revenues, enabling development and continuance of a program more able to meet planning needs. Further, a more long-range view may be expected from the state than from localities, which tend to concentrate on immediate gains and impacts.

---

[1] This includes the National Flood Insurance Program, the Coastal Zone Management Act of 1972, the Section 404 permit program of the Clean Water Act, and the National Scenic and Wild River program (Kusler 1980). Federal assistance for more general planning purposes is also provided through grants to planning agencies (for example, Section 701 of the Housing Act of 1954 to facilitate urban planning) or requirements for planning before federal grants are made (State Comprehensive Outdoor Recreation Plans, for example).

Public and intergovernmental involvement in a statewide comprehensive planning process can supply expertise, information, and communication to a degree not encountered in planning conducted at a more local level. More statewide visibility can produce a heightened public awareness of issues, including ground water protection, and perhaps greater acceptance of the decisions reached.

D. Disadvantages

Effective state land use planning would be widely perceived as a reduction of local autonomy; indeed one of its purposes is typically to reduce local public and private autonomy. Intergovernmental conflicts about the use and direction of planning and the degree of autonomy would be expected. State planning requires a financial commitment which may not have obvious benefits. Since existing data bases may be inadequate, comprehensive land use planning may require the development of an extensive data/information base.

The effectiveness of land use planning varies. The "quality of local plans and regulations, and the level of expertise used in administering them, often does not inspire confidence in the ability of...a more complex local-state program" (Council of State Governments, 1974). Because many planning agencies do not have implementation authority and because land use plans have only rarely been interpreted by the courts to set any constraints on governmental action, implementation of plans remains a major problem. To be effective, state planning requires local cooperation and regulation and mechanisms to promote intergovernmental coordination.

E. Feasibility

Legally, there is no reason why statewide planning cannot be initiated. It is not a new concept and has been implemented successfully in a number of states. In general, the major constraints to state comprehensive land use planning are political and institutional. Opposition stems from a view of state land-use planning as an increase in governmental control over private freedoms.

State level land use planning exists in Florida, Alabama, Georgia, and North Carolina (Council of State Governments 1974). Georgia, for example, passed the Metropolitan River Protection Act, which requires all construction within 2000 feet of a watercourse to be in accord with a metropolitan coordinated land and water use plan (Kundell 1980). North Carolina has developed a comprehensive land use planning process for coastal counties with substantial state involvement and direction (Healy and Rosenberg 1979). The experiences of Florida, Georgia, and North Carolina, although in some cases limited in geographic scope and in comprehensiveness, indicate that state comprehensive planning is feasible in the Southeast.

8.2.2 Land Use Information[1]

This section describes the potential value of land-use and water-use information to the develoment of ground water quality management in the South. Chapter 4 identified the importance of information to the problem-definition stages of ground water policy formation and suggested that ground water monitoring and modeling data for resolving ground water quality problems are limited. This section summarizes an approach to information, developed primarily by the New England states, which could be useful for comprehensive planning and ground water management.

Accurate and credible information enhances effective management of any resource; it can be particularly useful during the initial stages of policy formation to help diagnose the scope and seriousness of problems and to understand the range of potential policy responses. As states become more active in ground water management the need for accurate and credible information will increase.

A number of states are proceeding with innovative ground water quality protection programs based on a variety of solutions to problems of limited information (National Water Well Association 1982). The approach developed by the New England states is particularly interesting because of its potential applicability to other areas and because it is based on land use rather than ground water data. Based primarily on experiences in Connecticut, Vermont, Massachusetts, and Rhode Island, this approach emphasizes the role of land use in ground water protection. In this "land-use based" approach (Roberts and Butler 1983), information on land use is a primary component in problem definition. Mapped land use data, including the locations and capacities of existing and projected supply wells assists in the identification of present and future demands and stresses on ground water. Generally available mapped hydrogeological information on aquifer characteristics such as recharge areas, infiltration rates, and flow directions and rates can then identify with moderate accuracy probable and potential subsurface connections between demand and stresses. Identified conflicts between resource users then helps define the problem, focusing policy on the protection of ground water use.

---

[1] This section adapted from Roberts and Butler 1983.

B. Current Status

Three examples, from Cape Cod, Connecticut, and Vermont, illustrate the use of a land-use based approach in the formulation of ground water policy. Although the details of the approach to information differ, in each case land use data and limited hydrogeological information are combined to help define the ground water problems. The diversity of approaches for protecting ground water quality taken in these three examples indicates that an information base derived from land use data does not confine protection strategies to land use controls, but may expand the range of protection strategies.

The approach taken on Cape Cod toward ground water protection illustrates both the weaknessess of land use controls as protection tools and the value of land use data as an information base (Horaly 1982). Available information on the physical ground water resource permitted relatively simple analyses to delineate approximate "zones of contribution" for public supply wells on the island. A zone of contribution for a well identifies the land surface area from which water recharge collection, transmission, and storage occur. The physical data base is thus oriented towards protecting the most important uses of water and not the entire resource. Overlay mapping of the zones of contribution for public supply wells and the overlap of current or projected land uses demonstrated that potential ground water quality problems were serious and not completely solvable by land use controls. These constraints and concerns in addition to the specific nature of conflicts on Cape Cod, suggests an alternative approach to ground water protection. Since the ground water resource could not be changed and the threatening land uses could not be prohibited, technological modifications to these uses might reduce the risk to ground water supplies. The county developed three model regulations, only one of which involves zoning; at least one of these regulations has been adopted by 14 out of the 15 Cape Cod towns:

1. A water resource protection ordinance combining traditional and performance zoning for well recharge areas;
2. A toxic and hazardous materials control regulation requiring registration of firms handling such materials and proper utilization, storage, and disposal; and
3. An underground fuel storage tank regulation controlling the location and installation of tanks and requiring inventory control and leak testing for older tanks (Horaley 1982).

Connecticut has taken a much more comprehensive, centralized, and preventive approach to ground water protection than either Massachusetts or Vermont (Moore, 1982; Patton, 1983; Banach, 1983). The physical characterization of the resource is based on available information on surficial geology and assumes that ground watersheds follow surface watersheds. Ground water and land use information are added in the form of public supply wells, identified waste sources, protected areas, land use plans and controls. These maps formed the basis for problem identification and a ground water protection program. Connecticut chose to address the problem through a statewide aquifer classification system, based on the maps, which specified permitted land uses above given aquifers (see Chapter 6 for description of aquifer protection strategies).

Vermont developed information for policy decisions based on a pilot program involving 136 community water supply systems that served 30 percent of the state's population; additonal systems may be added in the future (Fischer 1982; Vermont Agency of Environmental Conservation 1982; 1983). The hydrogeologic component in the program delineated suspected recharge areas, or "Aquifer Protection Areas" (APAS), for public supply wells serving the 136 systems. A set of procedures were developed to use available information on surficial and bedrock geology, topography, soils, well logs, and engineering pump tests to more accurately delineate well recharge areas.

Once the Aquifer Protection Area boundaries were established, existing land use surveys mapped information on land uses. A comparison of existing land uses with town plans and land use regulations permitted the classification of each ground water system into categories depending on the conflict between land uses, ground water supply goals, and protection afforded by local regulations (Vermont Agency of Environmental Conservation 1983). The categories included: protected, possibly protected, minimally protected, and not protected. The Vermont mapping and classification systems are not regulatory devices in themselves; they are an information base for the use of all state and local agencies with missions relevant to ground water problems. This system estimates the pervasiveness of ground water quality problems with large magnitude consequences, determines the highest priorities, and focuses efforts on these priorities at low cost with limited available information.

C. Advantages and Disadvantages

A focus on land use data contributed to adaptable protection strategies because use patterns are more flexible than the physical hydrologic system. This approach only presumes a gross ground water model to define ground water problems, and reduces dependency on extensive ground water monitoring. Mapped land use and supply well data identify external demands and stresses on ground water (Prickett 1979). However, the land-use based approach can suffer from limited knowledge which reduces precision and accuracy. While this may limit the effectiveness of ground water management programs, the use of available information on hydrology and aquifer characteristics does allow reasonable judgements to be made about potential conflict between a land use and a ground water use.

The advantages of the land-use based approach in the definition of ground water problems are several. Data are available and relatively inexpensive (Fischer 1982; Moore 1982). The approach can be used to assess the seriousness and pervasiveness of problems. It suggests management approaches by identifying existing and potential resource use conflicts responsible for problems, permitting evaluations of the importance of these uses and the extent to which they can be modified. It can help to identify new management options based on altering existing uses, rather than on protecting the physical resource from change. This approach can also be used to target management approaches to areas with the most severe problems, and if problems are well-defined, applicaiton of management strategies may not require extensive monitoring and modeling.

D. Feasibility

The primary flexibility of the land-use based information approach may make it attractive in the Southeast, particularly in areas where concern over ground water quality and availability is rising and where land use controls are strongly opposed. However, since hydrogeological and ground water use patterns are different in the South than in New England, information systems are not directly transferable. In New England, the hydrogeology of public ground water supply and ground water contamination is a local, shallow phenomenon; almost all producing aquifers are water table aquifers. As a result, there is a direct relationship between the surface and the ground water beneath it, and local water supply wells are very sensitive to local land uses.

In the coastal plain of the southern states, the hydrogeology of ground water contamination is primarily based on gently dipping sedimentary aquifers. Conflicts between land and ground water users can therefore be either local or regional in nature and can occur in either confined or unconfined conditions. Unconfined aquifers that are highly vulnerable to local land uses occur at the outcrops of sedimentary strata. However, wells downdip from an outcrop, which tap that same stratum, may be sensitive both to the land uses at the outcrop and to more local land uses. In both cases, however, the hydrologic distance between the pollution source and the well intake may allow for attentuation of contamination; the degree of attenuation is dependent on the type of contaminant and characteristics of the strata through which it passes.

On the other hand, the hydrogeology of the fractured bedrock aquifers in the Piedmont and Appalachian areas is highly complex and less well understood than aquifers in the Coastal Plains. Typically ground water management in these areas has been very site-specific in nature rather than regional. However, the lack of information about the ground water systems makes comprehensive management difficult.

8.3. LAND USE CONTROLS

The police power of a state permits it to regulate the use of land in order to protect the public interest. Such regulation takes a variety of forms generally subsumed under the term, "land use controls". The most common forms include zoning, subdivision regulations, and building codes; land use controls are frequently the primary components of comprehensive land use plans.

Land use controls have been used in some locations to achieve ground water management goals. They can facilitate efficient ground water management by addressing a variety of purposes with the same basic institutional structure; that is, land use controls do not assume fixed forms serving fixed purposes. For example, zoning can be used to eliminate threatening land uses from recharge zones, to ensure that areas in which the ground water system is already stressed do not incur additional problems, or to require adequate distances between residential wells and septic tank drainfields.

This section discusses a variety of land use controls with particular potential for ground water management in the Southeast. Because land use controls represent a generic class of regulatory options, much of the discussion relative to their merits and their feasibility is common to many or all of the more specific forms. For this reason, Section 8.3.1 treats land use controls in general, recognizing commonalities among them. Zoning (8.3.2) and performance standards (8.3.3) are then discussed at length, followed by briefer discussions of the purchase of land or land rights (8.3.4), financial incentives (8.3.5), development and construction standards (8.3.6), and the use of land in conjunction with a ground water classification system (8.3.7).

8.3.1 Land Use Controls as a Class of Ground Water Management Tools

Legal and constitutional issues typically figure prominently in the debate surrounding adoption of land use controls in the Southeast. Since legislation and judicial interpretation differ from state to state, these issues are discussed in order to indicate the range of concerns relevant to ground water protection.

A. Current Status

In the past, almost all land use control powers have been exercised at the local level, either by municipalities or counties. These local powers derive from a state's delegation of its police powers through one of three instruments (Moss 1977):

1. State constitutional grant of home rule powers;
2. State statutory grant of home rule powers; or
3. State enabling act granting specific powers for specific purposes.

The type of delegation has implications for the land use management powers of localities. In general, constitutional or statutory home rule grants confer the authority to use a wide but unspecified variety of controls, but the authority to use a specific type of tool is subject to court interpretation. On the other hand, localities regulating under an enabling act have clear authority to use some specific land use control tools, but no others.

Grants by enabling act are further limited by a set of explicitly stated purposes for which delegated powers may be exercised. Ground water protection is not generally included, but protection of the public health and general welfare usually is. Because state courts today rarely distinguish between the statutory limits of such a statement and the constitutional limits of the police power, ground water protection is, in most cases, a valid purpose under such enabling acts (Harvard Law Review 1978).

In at least two southeastern states, enabling legislation for land use controls is direct. In Florida, utilization of land use controls to protect environmental and water resources is expressly encouraged. Florida's enabling legislation is based on the third draft of the American Law Institute's Model Land Development Code, which explicitly permits the protection of "land, air, water, natural resources, and environment of this state" through land use regulation. North Carolina's Coastal Area Management Act required coastal counties to plan to protect environmental resources and amenities. Although the Act legitimized land use controls to protect such resources, implementation of county plans has been only moderately successful.

The use by states and localities of land use regulatory powers to protect environmental resources, including ground water, is a legitimate exercise of the police power and has been upheld by various state and federal courts (Tripp and Jaffe 1979). However, constitutional constraints contained in the due process and takings clauses of the Fifth Amendment and in the equal protection clause of the Fourteenth Amendment place limits on the use of the police power to protect ground water.

The due process clause imposes a test of reasonableness on the ends and means; that is, the substance of the police power. To be reasonable the objectives of a regulation must promote the public health, safety, and general welfare and the means employed must be reasonably necessary to accomplish the objectives. However, the degree of proof required to support a reasonable relationship between means and ends is not rigorous. Evidence justifying the regulations is often considered sufficient even though disagreements may exist among experts (Selig 1982).

Because the protection of ground water can require severe restrictions on the permissible uses of land, the takings clause may be the major constitutional obstacle to the effective use of land use regulation (Harvard Law Review 1978). For example, it may be necessary to prevent any industrial or residential development in a critical recharge zone or prohibit the dredging and filling of wetlands. Imposing these restrictions could preclude development and reduce the value of property. In some states the criteria distinguishing between a valid exercise of the police power and a taking gives considerable weight to the size of the private burden or the reduction in property values. In these cases, land use restrictions to protect ground water might have difficulty surviving a takings challenge.

Courts in many states, however, will permit considerable reduction of property values under a number of conditions. These include cases where: (1) the public health or safety rather than the general welfare is at stake; (2) regulation prevents a public harm rather than creates a public benefit; or (3) a profitable use of land remains--such as farming, forestry, or recreation (Gleeson et al. 1975). Therefore, in many cases, the takings clause may pose a much less serious obstacle to ground water protection than is often supposed, particularly in the presence of statutory authority to use land use controls for that purpose.

The equal protection clause requires that regulations not discriminate unfairly between classes of property. To satisfy this requirement, any regulatory classification (such as a zoning classification) applied to otherwise similar properties must be reasonably related to the purposes of the authorizing legislation. Courts generally defer to a legislative determination that a classification rationally promotes a public purpose. Thus, land use regulation to protect ground water may be invalidated on the basis of its application to a particular land parcel rather than as a general policy. Invalidation may occur when limited standards or criteria provide inadequate guidance for the classification of land parcels. Consequently, successful equal protection challenges can impair the climate for protecting ground water through land use regulation.

B. Advantages

There are a number of advantages common to most of the specific land use management options. Perhaps the major advantage of land use management for protection of ground water derives from the explicit recognition of the interrelationship between land use and ground water quality and availability. Ground water problems can be approached directly by managing the relationship between the use of the surface and ground water. The approach is largely preventative and uses that create undesirable ground water changes or land uses sensitive to ground water inadequacies are controlled.

Land use management also has important advantages in the implementation and enforcement processes. Enabling legislation for many of the land use management options is already in place in all of the southeastern states (National Resources Defense Council 1977). In cities and some counties in the Southeast much of the basic regulatory and institutional structure exists in the form of zoning and other land use control ordinances, planning commissions, and administrative bodies within local government. Although the use of existing institutions can simplify and expedite the adoption and implementation of regulations to protect ground water, in some states modifications to enabling legislation need to be adopted to permit this direct protection of ground water.

Land use is also a visible feature of the landscape. For many types of land use controls it is easy to unambiguously determine compliance with regulations. This feature has led several states, including Connecticut and Vermont, to base their ground water protection strategies on land use management.

C. Disadvantages

The disadvantages of land use controls include: impacts on landowner and developer autonomy; bureaucratic red-tape; and potential limitations on land development, land values, economic growth, and housing availability. Land use controls to protect ground water can often be designed to minimize adverse costs, especially where trade-offs between environmental protection and other values are allowed. In many cases, however, the effort is not made.

A second set of disadvantages derives from disparities in the distribution of costs and benefits of land use controls. A small substate area may bear most of the costs to protect a much larger area. Where this occurs, land use management may not be the best tool to protect ground water unless some institutional mechanism is available to incorporate state or regional interests into local decisionmaking. A few landowners may incur significant costs to protect the water supply of an entire community. The potential for large, uncompensated losses can lead to regulatory ineffectiveness from the overuse of mechanisms such as variances that are intended to ensure flexibility and fairness (Gardiner and Lyman 1978).

Finally, a technological modification to a given land use or pollutant discharge limitation may be sufficient to solve the problem. Performance or construction standards for water supply wells or septic disposal systems are examples of technical fixes that may be more politically acceptable and cost less to implement than sweeping land use changes, yet reduce or eliminate a threat to the ground water system. However, implementation and enforcement may become difficult when the performance of a technology is in question or when the control variable is not the highly visible land use.

E. Feasibility

Major political constraints exist to the implementation of land use management powers to protect ground water, particularly in nonurban areas. In general, these constraints are more severe in the Southeast than in many other parts of the United States. The difficulties are reflected in the relatively low frequency of occurrence of land use regulation in the Southeast even though legislation delegating powers to cities and counties exists in all southeastern states. County governments, particularly in nonurban areas, have been particularly hesitant to exercise their land use control powers. Where county land use controls exist, they typically subject development to less stringent requirements than in many other areas of the country; their design, implementation, and enforcement is hampered by a lack of professional staff and effective means of enforcement, particularly in the smaller jurisdictions (Healy, 11). Cities in the Southeast typically have a full range of the traditional land use regulations, including zoning, subdivision regulations, and building codes; again, these regulations are frequently less stringent than in other regions, either in substance or application.

A 1980 survey of counties and municipalities (Regional Science Research Institute 1981) revealed that zoning to protect farm land is conspicuous by its absence in the Southeast (Figure 8-1). The use of innovative zoning powers to protect farmland as a valuable resource places major restrictions on the development potential of land; it therefore has many similarities to the use of zoning to protect ground water and, thus, may be an indicator of its political feasibility.

Political opposition to the use of governmental land management powers to protect ground water arises from several sources. Perhaps the most pervasive issue in the Southeast is the trade-off between the legitimate exercise of private property rights and protection of public interests. Southerners are often less willing to judge as fair an imposition of a private loss in order to gain a

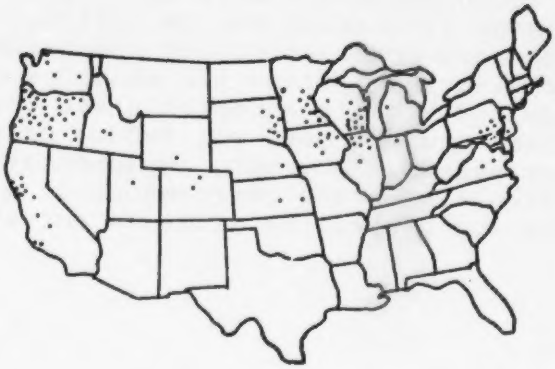


Figure 8-1: Counties and municipalities with zoning controls on agricultural land, 1980.

Source: Regional Science Research Institute 1981, 22.

public benefit. Both public officials and the general public often perceive an inappropriate taking where no basis for a constitutional taking exists. The "takings" issue is thus more a political than a constitutional problem (Healy and Rosenberg 1979, 233).

Land use control powers also generate intergroup conflicts. Support for the exercise of such powers generally arises from a small but vocal minority composed primarily of planners, environmentalists, citizen activists, and land use lawyers (Healy and Rosenberg 1979). These groups typically lack statewide political strength, organization, and economic influence. Although sympathy for the protection of the public interest through land use controls exists among a much wider segment of the population, active support from this group is often more elusive (Healy and Rosenberg 1979). The support of this wider segment of the population is most effectively mobilized when drinking water is at issue and when alternative means to ensure quality drinking water are less attractive (Yoder 1982).

Land use control or management may be opposed by coalitions of developers, the real estate sales industry, landowners and land speculators, farmers, the business community, labor, and civil rights and housing interest groups. In many cases the financial losses sustained by these interests are quite large; consequently, they are often well organized and able to exert substantial political influence. The validity of the objectives of ground water protection, and the stigma sometimes attached to some of the interests that oppose land use controls, may lead to an underestimation of the strength or the pervasiveness of the opposition to the exercise of public land use control powers. However, the concerns of many developers and builders is often not so much over the substance of regulations but over bureaucratic delay, red tape, and regulatory uncertainty.

F. Summary of Land Use Controls

In conclusion, land use controls can be an effective means to manage certain ground water quality or availability problems. Regulation of land use recognizes the hydrologic connection between the surface and subsurface environments. Compliance is in most cases easy to determine, facilitating enforcement. Enabling legislation and the basic regulatory apparatus is already in place in many parts of the Southeast, with some measure of public and judicial acceptance. Additional legislation at either the state or local level may be necessary in order to effectively ameliorate ground water problems, but in most cases neither state nor federal constitutional constraints pose insurmountable problems.

Land use controls to protect ground water face severe political barriers to adoption in much of the Southeast, with the possible exception of Florida and a few other locales. Land use regulation becomes more acceptable when human health, rather than the environment, is at stake and when due attention is paid to the concerns of those negatively affected. A variety of means exists to increase the political acceptability of land use regulation by reducing the costs imposed on individuals or groups. Such attempts to reduce or more equitably distribute the costs of land use controls are frequently themselves costly. However, they may significantly increase the political acceptability of regulation when the perceived benefits of ground water protection are high.

8.3.2 Zoning

A. Description

Zoning is one of the most common forms of land use control and one of the primary land use control techniques for water resource protection and management. Most state zoning enabling acts empower localities to restrict (National Resources Defense Council 1977):

- Use of land and structures;
- Size of lots;

- Height and size of structures;
- Percentage of the lot occupied; and
- Density of population.

Exercise of such powers can be used to eliminate or restrict land uses that have a significant impact on ground water. For example, industries that use hazardous materials can be prohibited from locating in recharge zones, or large recreational developments dependent on ground water can be prohibited from locating along ocean shores subject to salt water intrusion. Such land use powers can also be used to prevent the location of land uses sensitive to ground water problems in areas subject to those problems. Ground water dependent residential development may be prohibited in industrial zones where ground water quality may have been degraded or near large capacity agricultural or public supply wells with deep drawdowns. Zoning also can be used to reduce the amount of impermeable land cover and to indirectly control the density of residential wells or septic tanks through control of lot sizes.

There are a variety of forms of zoning which can be used depending on an area's particular circumstances. In its traditional form, zoning divides land into districts that have different development restrictions. Innovations developed to increase the flexibility of zoning and that may be appropriate to ground water management include:[1]

- Floating zones, in which purposes and standards for a district are established but the district is not located until a need is established;
- Overlay zones, in which additional standards are imposed overlaying other districts;
- Cluster zoning, in which units may be clustered on a land parcel as long as the required overall density is maintained; and
- Planned unit developments, in which development, generally on a large land parcel, may be exempted from the usual standards of a zone. Such dispensations are usually granted only if the development can meet a different set of standards, generally based on the aesthetic and functional quality of the design.

In general, overlay and floating zones allow additional standards to be applied in certain areas to reduce groundwater problems.

---

[1] Performance standards as a form of zoning is described in Section 8.3.3.

Cluster zoning and planned unit developments permit flexibility in development layout and design that could be used to either reduce ground water problems directly or to reduce the burdens of ground water protection on the developer or landowner.

B. Current Status

Enabling legislation exists in all southern states that grants cities and counties the power to adopt zoning ordinances. Most cities in the Southeast have exercised these powers, but relatively few counties have done so, particularly in rural areas. The extent to which localities in the Southeast with zoning ordinances have used them to protect water resources is unknown, but is probably much less frequent. Cities and suburban areas, however, are likely to consider septic tank pollutant loadings when setting minimum lot sizes in unsewered residential areas.

Two Florida counties are national leaders in using land use controls to protect ground water. Dade County has developed a zoning ordinance to protect public water-supply well fields by restricting the kinds and intensities of industrial land uses in well field "zones of influence" (Yoder 1982). The stringency of use restrictions decreases as a function of ground water travel time to the wells. Volusia County has established a zone called "potential recharge area" in which land uses were subject to additional regulations designed to protect critical ground water resources (Thurow, Toner, and Erley 1975).

New Hanover County, North Carolina, has been developing land use and ground water protection policies that call for zoning ordinance revisions to protect their primary aquifer recharge areas from high density urban, inappropriate industrial, and large-scale commercial development (Wilmington-New Hanover County 1981). In addition, the policies suggest modifying the zoning ordinance to permit greater design flexibility in order to cluster development, to protect natural drainage, and to decrease impermeable surface.

Other states and localities throughout the nation have experimented more extensively with the protection of ground water through zoning. Zoning controls to protect wetlands or valuable farmland are relatively common as are controls on lot sizes to protect septic drainfield function or to prevent excessive pollutant loadings from septic tanks. Both wetland zoning and large-lot zoning related to septic tank function have important ground water implications. Many states, particularly in the Northeast and Mid-Atlantic states, have developed zoning controls at either the local or state level to specifically protect well fields or ground water resources. Examples include cities and towns in Connecticut, Vermont, and Massachusetts, Suffolk and Nassau counties on Long Island, the Pine Barrens Regional Commission in New Jersey, and the city of San Antonio, Texas (Sixth National Ground Water Symposium

1982; Thurow, Toner, and Erly 1975). These zoning regulations typically control industrial land uses, landfills and other waste disposal activities, and septic tank densitites in critical recharge areas or in areas with high quality ground water.

C. Advantages/Disadvantages

The advantages of zoning are substantial. Zoning is probably the most widely used land use control technique to protect water resources because it is relatively easy to specify the development standards of a zoning ordinance unambiguously and to determine compliance. A number of states and localities have even developed zoning controls to protect ground water, providing valuable experience to other states or localities attempting to develp their own particular scheme.

The disadvantages of zoning revolve around the inflexible nature of the control and the widespread use of zoning to attain exclusionary objectives. Specifically, general classes of land uses are restricted rather than those aspects of land uses that cause the problem. For example, industrial land uses within a recharge area may be prohibited entirely rather than setting performance or technological standards that industrial users must meet. As a result, society loses the benefit of the use of land resources. Depending on the specifics of a given situation, these costs could range from minimal to highly significant.

Another problem associated with the use of zoning to protect ground water is a lack of adequate scientific or technical knowledge and experience concerning both the subsurface environment and the reaction of that environment to stress. Where aquifer recharge areas and ground water flow patterns are not well known, the identification of boundaries for protection areas is difficult. Likewise, the specification of standards or criteria to apply to land uses to prevent ground water problems is hampered by a lack of specific knowledge concerning pollutant loadings and the variable characteristics of soils and aquifers that may affect the behavior of pollutants in a given area. Without accurate knowledge, effective ground water protection strategies become increasingly difficult to design and to justify politically.

The effectiveness of zoning continues to be a controversial issue. The controversy revolves primarily around the ease with which variances and zone changes to an otherwise effective ordinance can be obtained. On the whole, zoning has been strongly criticized because of its dismal record of easily obtained exceptions in one form or another (e.g., Babcock 1966; Clawson 1971; and Hagman 1974). However, zoning has continued to be one of the most frequently implemented land use control techniques. In a study directed towards water management in California, Schwartz et al. (1979) concluded that a review of the available literature and the changing legal and political climate in California indicated that zoning had more potential than it was generally credited with. A recent evaluation of the effectiveness of existing farmland protection schemes relying on zoning (none of which were in the Southeast) concluded that agricultural zoning had been effective for prime farmland but not for marginal farmlands (Regional Science Research Institute 1981). This effectiveness was a result of the ability on the part of zoning administrators to discriminate between productive and unproductive farmland and of differences in the request rate for rezoning by the two types of landowners.

The ability of zoning administrators to apply a rational discretion where the objectives of the zoning ordinances is a widely supported resource protection strategy is encouraging for ground water protection. It is not clear that these more encouraging conclusions from other parts of the nation currently apply to the Southeast outside of Florida. However, they do indicate that zoning has considerable potential for ground water protection and could be a useful option in the Southeast.

D. Feasibility

As with most land use controls, there are far fewer legal constraints to adoption of zoning to protect ground water than there are political constraints. The permissable purposes in the Standard Zoning Enabling Act typically indicate zoning may be designed to promote health and the general welfare and facilitate the adequate provision of water, sewerage, and other public requirements. Such language indicates that, with care, zoning ordinances in most southeastern states can be designed under existing enabling legislation to protect ground water resources. In Florida and North Carolina, enabling legislation clearly encourages the use of zoning to protect ground water resources.

Zoning bears the full brunt of emotion, both positive and negative, attached to the public exercise of land use management powers. Where it is well established and reasonably effective, zoning represents one of the more feasible ways to protect ground water. Where zoning is not well established, opposition is often intense. In such cases, ground water problem-solving through zoning faces substantial political barriers.

Zoning to protect ground water may significantly reduce property values or expectations of future gains. Where technological options and design flexibility are perceived to provide equivalent amounts of ground water protection at a lower private cost, developers and landowners are able to marshal effective arguments against zoning.

The growing popularity of rural, semi-rural, and suburban living may also generate opposition to controls among a constituency that normally supports public land use controls. The use of zoning to protect ground water from septic effluent, or to protect households dependent on shallow residential supply wells from ground water contamination, may require prohibition of residential development requiring private wells or septic drain fields, or require lots so large they become prohibitively expensive.

It is difficult to gauge the strength of opposition to zoning in the Southeast. The fewest constraints are found in Florida, with its metropolitan population and its high proportion of migrants from other parts of the country, and in the coastal zones of states with important shoreline recreational resources. The greatest constraints are found in rural areas that have not experienced strong economic growth over the past few years. Even many urban and metropolitan areas with established zoning ordinances may find it difficult to adopt a zoning policy to protect ground water if it appears that the regulations will be enforced; zoning has been politically acceptable in some of these areas only because it has been generally ineffective.

8.3.3 Performance Standards

A. Description

Instead of specifying land uses, construction techniques, or site requirements, performance standards define the maximum permissable impact of land uses. Such standards shift the primary focus from what is on the land to how the land functions. Because impacts of land uses are of primary concern in environmental protection, performance standards may be particularly appropriate for land use controls designed to protect ground water. For instance, traditional zoning and subdivision regulations designed to prevent runoff and protect recharge might specify the maximum percentage lot cover, permissable alterations to natural water courses or the land surface, and detailed design and construction guidelines for storm water management. A performance standard, on the other hand, might specify only a maximum percentage runoff over a period of time; it would be up to the land user or the developer to design developments or land use practices so that the performance standard is not violated. Land-use performance standards are a more general application of such performance standards as discharge restrictions nondegradation, and aquifer classificaiton strategies (see Chapter 6).

Land use performance standards are generally implemented through two alternate approaches (Thurow, Toner, and Erly 1975). Most commonly, performance standards are implemented as a second layer of control in addition to zoning. The zoning ordinance specifies a series of general uses permitted outright in a district, along with a series of uses requiring a special permit; performance standards are the criteria used in the granting of special permits (see Chapter 6 for a discussion of discharge permits). Less frequently, performance standards are the first level of control; all uses are permitted as long as they meet the performance standards.

B. Current Status

The history of land use controls in the United States has been characterized by a gradual shift from specification standards to performance standards (Thurow, Toner, and Erley 1975). The first widescale applications of performance standards were to industrial districts in the 1950s and involved noise, vibration, air pollution, and other standards. Since then, they have been used increasingly in a wide variety of land use controls, particularly for uses subject to special permitting procedures. Many land use regulations having environmental protection has a major goal incorporate performance standards because they address environmental concerns much more directly than most specification standards. Examples of the use of performance standards to protect ground water include Volusia County, Florida; Orono, Minnesota; and Cape Cod, Massachusetts.

The Volusia County ordinance required permits for virtually any changes in land use in the aquifer recharge area; permits are granted only if the County Council finds, on the basis of an impact statement, that the development would not have any impact on recharge (Thurow, Toner, and Erley 1975). The Floodplain and Wetlands Ordinance of the village of Orono prohibits the granting of variances in designated areas if the development would have a tendency to "be detrimental to the protection of surface and ground water supplies" or would develop areas essential to ground water infiltration (Thurow, Toner, and Erley 1975).

A number of towns on Cape Cod have adopted one or more of three model ordinances designed to decrease the threat to the sole source aquifer which supplies the area. All three ordinances have incorporated performance standards (Cape Cod Planning and Economic Development Commission 1981). One prohibits the discharge of toxic or hazardous materials and requires the secure storage of such materials. to be secure. A second requires owners of underground fuel and chemical storage systems to demonstrate upon request an accurate inventory control system and to periodically demonstrate that older tanks can pass a leak detection test. A third ordinance permits certain uses in water resource districts only if: (1) it is determined that on-site waste disposal and operations will not permit ground water quality to fall below federal or state drinking water standards; and (2) and that any control measures proposed are feasible and reliable. In addition, a number of communities, including DeKalb County, Georgia, and Marion County, Florida, use performance standards to control erosion and runoff (Thurow, Toner, and Erly 1975); although most of these regulations are not directed at ground water protection, they could easily be modified to do so.

C. Advantages

Performance standards have a number of important advantages. They can frequently be adoped at the local level under existing state enabling legislation, although new legislation or modifications to existing legislation might remove some barriers (Thurow, Toner, and Erley 1975). Where local zoning, subdivision, and other land use controls are already in place, performance standards can be adopted as a modification to existing ordinances and implemented using institutions already in existence. As a result, in many locations performance standards represent a gradual evolution of land use regulation rather than an abrupt change.

Performance standards permit greater design and construction innovation and flexibility than do specification standards; consequently, can be less costly and more politically acceptable. Because performance, and not use or technology, is specified, the developer or land user is free to choose a technology to meet the standard. Performance standards, therefore, tend to encourage innovation to improve the compatibility of land uses with the environment and to meet the standard at lower cost. Further, performance standards permit case by case consideration and adaptation of controls to specific sites. Uses that present no danger to ground water, and sites possessing characteristics that protect ground water, are not subjected to restrictions. Controls that clearly addresss ground water problems, and that do not impose restrictions on land uses or sites that pose no threat to ground water, may be much more acceptable to both land users and the courts than the more traditional controls.

Finally, performance controls offer some administrative advantages. Because they directly regulate environmental impacts they may eliminate the need for the inclusion of acceptable design specifications. The burden of demonstrating that a technology will meet the performance standard lies with the landowner. Written regulations can be simplified because the environmental standard can usually be stated much more simply than design standards.

D. Disadvantages

Peformance standards also have a number of significant disadvantages. Specifying standards in terms of performance does not diminish the difficulties of determining what those standards should be. The determination of an acceptable impact is not just a technical issue but involves judgments and political and legal considerations. These problems become especially critical if the performance criteria are stated in general terms, such as "no harmful impact on ground water." In these instances, the uncertainties associated with value judgements and political considerations become a significant element in the decision on each permit application. If the performance standard is stated as a specific numerical standard, considerations can be focused more clearly on the statement of policy as defined by the standard; decisions on individual permit applications would focus more on scientific and technical issues. However, flexibility to consider nontechnical issues or to adjust the standard to specific circumstances is reduced.

Implementation of land use performance standards also places a considerable burden on administering agencies, both in terms of the technical expertise and staff time required. Evaluating permit applications to determine if they meet the standard is much more difficult for performance standards than for design standards (see Section 6.6). Although most such regulations shift much of the burden of demonstrating that the technologies used will meet the standard to the applicant, the administering agency must still be able to devote a considerable amount of time and expertise to evaluating documentation supplied by the applicant. Further, adequate models to predict the impact of a technology exist for only a few land functions, such as run-off and erosion (Thurow, Toner, and Erley 1975). Where models are very inadequate, the use of performance standards may generate considerable uncertainty on the part of both administering agencies and developers.

Finally, land use performance standards can be technically difficult to enforce if based on measures of actual performance rather than on inspecting the deployment of technologies designed to achieve that performance. This may be particularly true for ground water, given the difficulty of monitoring ground water and of remedying contamination once it occurs. As a result, most land use controls based on performance standards use the standard as a criterion by which to permit a use or a technology. Determination of compliance is therefore simplified to the determination of whether the use or technology is as specified by the permit.

E. Feasibility

Land use performance standards have considerable promise for ground water protection. They are frequently perceived to be less restrictive than traditional zoning and subdivision controls and may encounter fewer political barriers. Where other land use controls are in effect, they represent an evolutionary rather than a revolutionary change in regulation. They address environmental concerns directly and can operate to decouple two very different goals of land use regulation--environmental protection and the shape and function of surface development. A disentangling of these different purposes may increase the effectiveness and the political feasibility of ground water protection through land use controls. By tying the regulations to existing land use laws, in some cases land use performance standards may be more feasible than developing new ground water quality laws.

On the negative side, land use performance standards make heavy demands on our available knowledge base and on the technical expertise and financial resources of administering agencies. Where adequate knowlege, expertise, and financial resources are not available, the increase of uncertainty and discretion that can accompany such problems may decrease the effectiveness of performance standards in protecting ground water and increase the political and constitutional obstacles to their adoption and implementation.

8.3.4 Purchase of Land or Land Rights

A. Description

Outright purchase, or full-fee acquisition, of land has long been an option of governments for a variety of purposes. Landowners may choose to sell to the government voluntarily, or, if the property serves a legitimate public use, government may condemn land and force landowners to sell through its right of eminent domain. The condemnation process is normally avoided because it is uncertain, lengthy, costly, and a poor public relations practice. Alternatively, a government may acquire easements, or rights to certain uses, including rights to require the landowner to forego given uses of the land.

Government purchase and holding of land, or "land banking," could provide an effective tool for the protection of both ground water quality and availability. Land banking for ground water protection would generally involve purchasing land in important ground water recharge areas and maintaining it in a relatively undeveloped state to protect both the quality and quantity of recharge. The protection of major portions of aquifers through land banking would generally require the purchase of large tracts of land, unless recharge areas were very small, and could be very expensive. The protection of important wells or well fields, on the other hand, would require much smaller areas of land.

B. Current Status

Though government purchase of land is used widely, purposes of acquisition vary and the purchase of land to help meet ground water management goals is relatively infrequent. A joint state-federal program for the acquisition of land in the Big Cypress Swamp in Florida, which "has a direct relationship with the freshwater aquifer which supplies water for nearly all of the people of South Florida," has been established (Schnidman 1980). Outside the Southeast, the state of Vermont has suggested that towns consider the purchase of land in aquifer protection areas surrounding public supply wells and has even prepared cost estimates for such purchases for each of the aquifer protection areas (Fischer 1982). The purchase of important ground water recharge areas also figures prominently in a proposed plan for the protection of Long Island's water supply (Coalition for the Protection of Long Island's Ground Water 1982). The purchase of land or the retention of existing publically owned lands has been much more frequently used for the protection of surface watersheds.

C. Advantages

A number of advantages may be realized if land is purchased for ground water management, in terms of acceptability and the supply and quality of water. Purchase of land or land rights provides compensation to landowners for monetary losses sustained as a result of ground water protection. As a result, it is much more acceptable to those negatively affected by ground water protection than are similar management strategies implemented through regulation only. In fact, land banking of recharge zones may afford the maximum possible protection of resource lands for water quality and quantity objectives (Schwartz et al. 1979). If surface flow and percolation are protected, both the capital and operational costs required to maintain desired supply and quality may be lower. For example, the expense of additional wells, surface supply facilities, or water treatment may be avoided (Schwartz et al. 1979). The same may be true when undeveloped land is utilized as catchment basins to reduce storm runoff and increase infiltration. Depending on the extent of protection provided for in easements, acquisition of land rights could have benefits similar to those associated with full-fee acquisition. Additionally, costs of acquisition would be lower, less tax income would be lost, and fewer condemnation proceedings would be required.

D. Disadvantages

The drawback of land-banking programs is the high cost. Full-fee acquisition is the most expensive, but the purchase of more limited rights is frequently almost as expensive because the development rights are the major source of land value. Along with high acquisition costs, government property tax revenues are reduced. Moreover, land prices are often higher when the purchaser is a government body. If condemnation is required, it can be lengthy, costly, and often a cause of adverse publicity. The choice may be made to forego land or rights acquisition rather than acquire by condemnation. The purchase of limited rights provides less protection than acquisition and fewer land management options, but many of the same costs and disadvantages of full-fee acquisition still apply.

E. Feasibility

Legally, the public purchase of land is quite feasible, particularly where sales are voluntary. Feasibility is somewhat more restricted when questions of condemnation come into play. However, when water management objectives are specified, land acquisition "should be better able to pass the test of meeting a specific public purpose" (Schwartz et al. 1979). Political subdivisions within critical recharge or other potential protection areas may be a source of additional barriers. Cooperation is needed between political entities to acquire land in different jurisdictions; purchase by a single entity (other than an all-encompassing body, such as the state) throughout an area could be disfavored and difficult. Schwartz et al. (1979) judge administrative, financial and political feasibility to be low. If land rights or easements are acquired, rather than full title, feasibility may be greater since the costs are likely to be lower.

8.3.7 Financial Incentives

A. Description

Incentives that provide a financial benefit to landowners encourage land uses that will protect ground water. The most common forms relevant to ground water protection include differential assessment, property tax credits, and transferable development rights. Governmental purchase of land or development could also be considered a financial incentive (see Section 8.3.4). Two types of tax incentives provide benefits to landowners in ground water management areas: (1) differential assessments which value land in highly managed areas at lower rates; and (2) tax credits which allow landowners a credit either against local taxes or against state income taxes. In some cases, landowners are either subject to land use controls or must enter a restrictive land-use agreement in order to obtain the tax benefits; in other cases, the incentive is provided with no such restriction.

A transferable development rights (TDRs) program facilitates the purchase of development rights from landowners in ground water protection areas. These rights, aquired through purchase of TDR permits can be transfered to a designated new development area and an equivalent amount of additional development can be constructed. A TDR program thus creates a semi-private market in development rights.

B. Current Status

Most experience with financial incentives for land use control has been in agricultural land protection programs, where such incentives are common. Differential assessment for farmland protection programs are found in almost all states; property tax credits programs are found in Michigan and Wisconsin (Coughlin and Keene, n.d.). There are approximately a dozen transferable development rights programs for farmland protection in existence, primarily in New York, New Jersey, and Pennsylvania. A number of localities, including Long Island in N.Y., Dade County in Florida, and the Pine Barrens of New Jersey are implementing or seriously considering transferable development rights programs for ground water protection.

C. Advantages/Disadvantages

Farmland protection and ground water protection through land use programs are sufficiently similar--both require severe restrictions on permitted land uses--that the experience with one may be transferable to the other. The most significant conclusions from a decade of experience with financial incentives for farmland protection is that such measures are ineffective when implemented alone; the financial incentive to develop land usually overwhelms the amount the public is willing to pay (Coughlin and Keene n.d.). As a result, such incentives may turn into subsidies with limited public benefit.

However, financial incentives have a very significant positive role in combination with other types of controls on land use. One of the major constraints to the adoption and effective implementation of land use controls, such as zoning or development standards, is that they impose unequally distributed burdens on individuals in order to obtain public benefits. Providing a financial benefit paid by the gainers to the losers distributes the burden more equitably and increases the perception of fairness on the part of both gainers and losers. Financial incentives may diminish some of the cash flow problems that can become factors in landowners' decisions to develop. Financial incentives receive wide support from the general public when the burden on landowners is perceived to be substantial, where the burden is clearly unfair (e.g., basing property taxes on the highest and best use when such uses are prohibited), or where the burden falls on groups (e.g., farmers or the elderly) for whom considerable public sympathy exists. Incentives therefore, provide a means to increase the fairness and political acceptability of land-use controls designed to protect ground water.

Financial incentives (other than TDRs) can be expensive in terms of revenues foregone. Property tax incentives may be easier to adopt than such measures as purchase or development rights; even if the actual costs were very similar, they are financed through tax revenues foregone rather than increased taxes. State income tax credits, which do not reduce local revenues and which transfer the burden of financing incentives to the state as a whole, may further reduce the apparent cost of financing incentive programs.

However, where the public cost of a program is not clearly perceived, a political determination may not develop to ensure that land-use controls are sufficient to provide public ground water protection benefits.

Transferable development rights (TDRs), in contrast, do not impose direct burdens on public treasuries. In fact, much of their appeal derives from the fact that incentives are paid by those landowners or developers who gain to those who lose as a result of land-use controls designed to protect ground water. Although TDRs continue to receive much interest, the concept is so new that its promise cannot yet be fully evaluated. Many of the practical and institutional details related to effective implementation and public support and acceptance remain to be worked out (Healy and Rosenberg 1979; Coughlin and Keene n.d.). TDR programs are authorized in a number of areas, but few transactions have actually taken place. The potential of TDR programs is sufficient, however, to encourage continued experimentation in their use.

8.3.6 Development and Construction Design Standards

Development and construction regulations specify design standards for land division, construction, and other types of development or land use change. In most cases, the standards prescribe mandatory technologies. Such regulations are typically implemented through the granting of discretionary permits, on the basis of an on-site inspection, or engineering plans submitted in the permit application. Subdivision regulations, building codes, and dwelling occupancy codes are the most common forms of such regulations, but similar regulations prescribe standards for other types of development: dredge and fill operations in water courses, wetland modifications, and development in flood plains, for example. There is no conceptual reason why development regulations cannot be designed specifically for the purpose of protecting ground water.

The applicability of such design standards to ground water protection is clear. Standards can specify design criteria and permissable technologies for surface and vegetation modification, changes in natural drainage, the provision of artificial drainage, the percent of land area covered with impermeable surface, land dedication for open space or other uses, and provision of water supply and sewage disposal. Standards in each of these categories can be designed to reduce pollutant loads to ground water.

Subdivision and building regulations are permitted under existing enabling legislation in all southeastern states; however, not all local jurisdictions, particularly nonmetropolitan counties, have adopted such regulations (Natural Resources Defense Council 1977). Some states have extensive legislation. Florida and North Carolina permit a wide variety of stringent development regulations to protect water resources, particularly designated areas of concern (Kusler 1980). The states of Mississippi, Georgia, and Alabama set standards for development in coastal wetlands through a permit system and Kentucky similarly regulates development in floodways (Kusler 1980).

Although design standards do not restrict land uses themselves and may therefore initally be thought to be less effective for protecting sensitive recharge areas, they do have a number of advantages. They are among the most effective land use management techniques in terms of ensuring that development occurs according to the stated regulations. As a result, they are widely regarded as among the most effective land use management techniques for achieving environmental objectives (Kaiser et al. 1973). This effectiveness derives, in large part, from the widespread acceptance by both the public and developers of the purposes and the substance of such regulations. Because development regulations do not prohibit uses, they are widely accepted. Not only are development standards more effective and more politically acceptable, but the resource costs of complying with the regulations are frequently less because the uses of valuable land resources are not foregone. Development regulations have generally been well received by the courts as long as the standards are demonstrably related to the public welfare and clear enabling authority from the state exists (National Resources Defense Council 1977).

Disadvantages of design regulations primarily revolve around the static and inflexible nature of most design codes and the public and private costs of administration. The development of appropriate design standards requires considerable technical and legal expertise, and therefore cannot be frequently modified. Once codified, such technological standards become difficult to change, inhibiting the development and use of less expensive or more effective technologies. Also, such regulations can never take all the variables applicable to a given development into account. Consequently, standards are generally pegged to an average case or some minimum level of risk. Developers understandably resent codes when the standard is not appropriate for a given case or when some other technology is more effective and/or less costly. If design regulations are so stringent as to prohibit development rather than subject it to reasonable standards, opposition from developers mounts dramatically. Attempts to use design standards regulations to achieve objectives more appropriate to zoning regulations are therefore much less effective and less politically acceptable; in general such stringent regulations are not allowed by the courts (Mandelker and Cunningham 1979).

The public costs of regulation administration and private costs of compliance are frequently high. Public costs include time and expertise reviewing designs, public hearings, on-site inspections, and permit administration systems. Although the costs of technical compliance is substantial, of greatest concern to developers are the costs of delay and uncertainty.

In sum, design regulations are among the most effective and politically acceptable land use controls. This is particularly true in the nonmetropolitan Southeast where zoning and other controls have relatively less support than in other parts of the nation. As a result, where reasonable technological modifications to land uses can ameliorate ground water problems, they are particularly attractive. Although enabling legislation may be necessary in many southeastern states to facilitate the local adoption of certain forms of design regulations, those enabled under existing legislation (e.g., subdivision, building, wetland, and floodplain regulations) can frequently be modified to take ground water concerns into account.

8.3.7 Ground Water Classification System Based on Land Use Standards

The use of land use controls or standards to implement a ground water classification system (see Section 6.6.5 for a discussion of classification systems) offers a means to translate the concept of classification into an effective ground water quality management strategy. For example, instead of defining standards for the various aquifer classifications in terms of maximum pollutant levels in ground water or in discharge streams, Connecticut defines these standards in terms of the land uses that are permitted in aquifer recharge areas. In Connecticut the land use standards are implemented through a state-administered discharge permit system. Connecticut chose a system based on land use standards because it would: (1) simplify monitoring and determination of compliance; (2) facilitate the prohibition of certain high risk land uses; and (3) encourage localities to reinforce state efforts through local land use planning and controls (Moore 1982). New Hanover County, North Carolina has also explored this possibility for recharge areas. However, by conceptualizing ground water protection in terms of prohibiting risky land uses, less costly choices that only modify land uses may be overlooked.

8.4 SITING PROCEDURES FOR HIGH RISK FACILITIES

A. Description

Siting involves the setting of controls on the geographical locations of major potential ground water polluting and/or depleting activities and facilities. Higher risk land uses that may be subject to such controls include landfills, mines, hazardous waste disposal facilities, impoundments, energy facilities (power plants in particular), and certain other industries when on a large scale. For example, large industrial parks and such industries as paper mills, food processing, chemicals, and textiles can affect ground water. These types of land uses can be located in areas of minimal hydrologic/ground water sensitivity, avoiding important recharge areas and other vulnerable sites.

Siting of facilities occurs within a complex framework of federal, state, and local laws and regulatory programs, with the possibility of judicial review of governmental decisions (Baram 1976). Laws and regulations which currently apply to siting have been developed with many different basic purposes and criteria. The complexity of the system, the lack of comprehensive approaches, and differing interests at various governmental levels have made decision-making and control of siting difficult.

The siting process has tended to be "reactive," in that industries make initial site selections to which regulatory bodies must then respond by granting or denying permit requests (Science and Public Policy Program 1981). In some cases, large companies will engage in overall system planning to aid in their siting decisions; however, industrial criteria for siting may not include ground water quality and availability concerns. Even government agencies with some control over siting may fail to take ground water concerns into account when developing siting criteria. The American Bar Association suggested the creation of both federal and state "super siting agencies" to broaden siting decision considerations for major industrial development proposals (Baram 1976). A discussion of siting policy options relevant specifically to hazardous waste facilities is included in Chapter 6.

B. Current Status

Where siting programs exist in the Southeast, they seem to be directed primarily to energy facilities and hazardous waste facilities. Comprehensive facility siting programs for ground water management or other purposes generally do not exist. Energy facility siting programs vary widely. As of February 1978, Alabama had no state-wide siting program and Mississippi had no specific statute. On the other hand, the 1976 amendments to Florida's Electrical Power Plant Siting Act of 1974 provide for inclusion of "water management districts as a statutory party" and for assessment of compliance of siting with the State Comprehensive Plan (Southern States Energy Board 1978).

As discussed in Chapter 6, several types of control exist for hazardous waste facility siting. Local authorities have complete control of siting in Alabama and South Carolina. In several cases the state legislature has some level of authority over local government; complete state control over all local decisions exists in North Carolina and Florida; Georgia, and Mississippi have varying levels of preemptive authority. Tennessee has instituted a state board for siting hazardous waste facilities (Science and Public Policy Program 1983).

C. Advantages

A centralized state approach to the siting of facilities could help lead to the development of sensible land use patterns with minimal ground water. Rather than narrow local interests controlling facilities placement (which at times means no control at all), regional welfare would be considered. A state program could improve coordination and consistency in the siting process by bringing together the regulations and activities presently scattered across the jurisdiction of many agencies. In addition, the siting processes can help focus public attention on ground water problems and growing concern with ground water quality and availability may result in more supportive views of state decisions.

D. Disadvantages

The disadvantages of a state approach include costs of establishment and administration; the complexity of ordering scattered laws, regulations, and activities; and possible conflicts among governmental levels and agencies. It would be difficult to devise siting criteria for a state program that would meet the approval of all involved and balance ground water protection and economic development. It may be possible to devise a set of criteria for excluding areas from acceptable facility sites, map the areas, and find no acceptable sites for the facility in question.

Loss of some local autonomy would probably occur, and review processes implemented could increase regulatory delays or hamper industrial/economic growth. However, the process would focus public attention on siting decisions and provide a forum for opponents of locational decisions; the siting of necessary but locally undesirable facilities could meet stronger opposition than without such a process. Initial program development could be costly, and review process instituted would likely be both expensive and lengthy, adding financial risk to the proposed facility as well as administrative costs to the state.

E. Feasibility

There are no major constitutional constraints to state siting programs. However, such programs would likely meet with strong political opposition in southern states. Desires of local governments for autonomy and open-ended development, along with southern feelings against government interference, would have to be overcome.

Many areas within the Southeast are promoting and actively seeking industry, including many industries that could be a high risk to ground water. This active industrial expansion and strong desire for economic growth can lead to strong pressures for accomodation of industry and may not be conducive to careful siting. Indeed, in a region that, for the most part, actively resists zoning (which seems to be an easier form of control) siting programs would likely be even more difficult to implement with any degree of effectiveness.

8.5 SUMMARY

Land use contorls and data can be an effective, and in some cases necessary, approach for managing ground water quality and availability. Although land use controls are widespread, they have not been applied on a regional basis to improve ground water management in the Southeast. Among those approaches that have been implemented in some areas are zoning controls, subdivision regulation, and on a much more limited scale, comprehensive planning, performance standards, and centralized siting processes. Almost no attention has been given to ground water management using financial incentives or land use based aquifer classification systems in the Southeast.

Despite the limited implementation of land use management for ground water protection, a legal basis exists in most southeastern states for adopting many of the land use management options discussed in this chapter. Political opposition is likely to occur, however, if land use policies appear economically restrictive.

Land use controls are not likely to achieve rapid improvements in ground water problems, however, they offer alternatives for helping to mitigate availability and quality concerns. Further, land use management generally has a broad data base, and an extensive foundation of administrative experience. For some states it may be one effective means for future improvement in ground water protection without requiring an extensive new legislative basis.

REFERENCES

Babcock, Richard F. 1966. The Zoning Game. Madison: University of Wisconsin Press.

Banach, Fred. 1983. Connecticut Department of Environmental Protection. Personal communication, February.

Baram, M. S. 1976. Environmental Law and the Siting of Facilities: Issues in Land Use and Coastal Zone Management. Cambridge, MA: Ballinger.

Cape Cod Planning and Economic Development Commission. 1981.

Clawson, Marion. 1971. Suburban Land Conversion in the United States. Baltimore, MD: Johns Hopkins Press.

Couglin, Robert E., John C. Keene, et al. 1981. The Protection of Farmland: A Reference Guidebook for State and Local Governments. By the Regional Science Research Institute for the National Agricultural Lands Study. Washington, DC: Government Printing Office.

Council of State Governments. 1974. Land Use Policy and Program Analysis Number 1: Intergovernmental Relations in State Land Use Planning. Lexington, KY: Council of State Governments.

Fischer, Cheryl K. 1982. "Designing Aquifer Protection Areas in Vermont." Presented at the Sixth National Ground Water Quality Symposium, Atlanta, GA, September 22-24.

Gardiner, John A., and Theodore R. Lyman. 1978. Decisions for Sale: Corruption and Reform in Land-Use and Building Regulation. New York: Praeger.

Gleeson, Michael E., et al. 1975. Urban Growth Management Systems: An Evaluation of Policy-Related Research. Planning Advisory Service Report nos. 309, 310. Chicago: American Society of Planning Officials.

Greenberg, Ellen, Sarah Meland, and James T. B. Tripp, eds. 1982. Watershed Planning for the Protection of Long Island's Groundwater. N.p.: Coalition for the Protection of Long Island's Groundwater.

Hagman, Donald G. 1974. "Windfalls for Wipeouts." In The Good Earth of America, edited by C. Lowell Harris, 109-33. Englewood Cliffs, NJ: Prentice Hall.

Harvard Law Review. 1978. "Developments in The Law: Zoning." 91:1427.

Healy, Robert G., and John S. Rosenberg. 1979. Land Use and The United States. 2nd ed. Resources for the Future. Baltimore, MD: Johns Hopkins Press.

Horsley, Scott W. 1982. "Beyond Zoning: Municipal Ordinances to Protect Ground Water." Presented at the Sixth National Ground Water Quality Symposium, Atlanta, GA, September 22-24.

Kaiser, Edward J., et al. 1973. Promoting Environmental Quality Through Urban Planning and Control. Washington, DC: Environmental Protection Agency, Environmental Studies Division.

Kundell, James E., ed. 1980. Georgia Water Resources: Issues and Options. Athens: University of Georgia, Institute of Government.

Kusler, John A. 1980. Regulating Sensitive Lands. Cambridge, MA: Ballinger.

Mandelker, Daniel R., and Roger A. Cunningham. 1979. Planning and Control of Land Development. Indianapolis, IN: Bobbs-Merrill.

Moore, Robert E. 1982. "Defining the Basic Objectives of a Ground-Water Program." Presented at the Sixth National Ground Water Quality Symposium, Atlanta, GA, September 22-24.

Mushkatel, Alvin H., and Dennis R. Judd. 1981. "The States' Role in Land Use Policy." Policy Studies Journal 1:263-74.

National Resources Defense Council, Inc. 1977. Land Use Controls in the United States: A Handbook on the Legal Rights of Citizens. Edited by Elaine Moss. New York: Dial Press/James Wade.

Popper, Frank J. 1981. The Politics of Land-Use Reform. Madison: University of Wisconsin Press.

Prickett, Thomas A. 1979. "State-of-the Art of Groundwater Modeling." Water Supply and Management 3: 131-41.

Roberts, Rebecca S., and Lisa Mathis Butler. 1983. "Land Use and Groundwater Policy Formation." Presented at the 61st Annual Meeting, Southwestern Social Science Association, Houston, TX, March 23-26.

Schnidman, Frank. 1980. "To Buy or Not to Buy, That is the Question." In *Management and Control of Growth*. Vol. 5, *Updating the Law*, edited by Frank Schnidman and Jane Silverman, 120-22. Washington, DC: Urban Land Institute.

Schwartz, Seymour I., et al. 1979. *Controlling Land Use for Water Management and Urban Growth Management: A Policy Analysis*. Davis, CA: University of California, California Water Resource Center.

Science and Public Policy Program. 1981. *Energy From the West*. Norman: University of Oklahoma Press.

________. 1983. *Southern Regional Environmental Assessment*. Washington, DC: U.S Environmental Protection Agency.

Southern States Energy Board. 1978. *Energy Facility Siting in the United States*. Vol. 1, *Executive Summary*. Atlanta, GA: Southern States Energy Board.

Thurow, Charles, William Toner, and Duncan Erley. 1975. *Performance Controls for Sensitive Lands: A Practical Guide for Local Administrators, Parts 1 and 2*. Planning Advisory Service Report nos 307, 308. Chicago: American Society of Planning Officials.

Tripp, James T. B., and Adam B. Jaffe. 1979. "Preventing Groundwater Pollution: Towards a Coordinated Strategy to Protect Critical Recharge Zones." *Harvard Environmental Law Review* 3 (1): 1-47.

Vermont Agency of Environmental Conservation. 1982. *Vermont Ground Water Protection Strategy*. Montpelier, VT, October

Vermont Department of Water Resource and Environmental Engineering. Water Quality Division. 1983. "Vermont Aquifer Protection Area Reference Document." Montpelier, VT, March.

Wilmington and New Hanover County Planning Departments. 1981. *Policies for Growth and Development*. Wilmington, NC: Wilmington and New Hanover County Planning Departments.

Yoder, Douglas. 1982. "The Biscayne Aquifer Project: Local Well Field Protection Program." Presented at the Sixth National Ground Water Quality Symposium Atlanta, GA, September 22-24.

CHAPTER 9

STATE AND LOCAL INSTITUTIONAL DEVELOPMENT

9.1 INTRODUCTION

Chapters 4 and 5 of this report have documented two general reasons why it is important to address state and local institutional options for managing ground water. First, several political trends strongly indicate that the federal role in managing natural resources will diminish in the foreseeable future. Thus, state governments will have increased management responsibility. Because southeastern states can be expected to continue to experience industrial and population growth over the next two decades, they are likely to be forced to deal more directly with the need to balance water resource policy and growth policy, including issues such as the adequacy of ground water to meet new demands and controlling threats to ground water quality.

Second, institutional development for ground water management is a relatively recent trend in the Southeast; historically the abundance of water in the Southeast has meant that water issues have not been significant enough to require a strong state role. However, concerns about ground water resources are increasing rapidly and considerable attention is now being paid to developing state institutional capacity (see Chapter 4).

The following specific problems which may require new or revised state institutional approaches have been identified in chapters 4 and 5.

- Since ground water has been viewed as an individual right, the legal systems for allocating ground water and water rights doctrines frequently limit the state role to preventing or settling desputes among users (Chapter 5.3.2). For states to exert an active ground water management role, new or revised legal/administrative approaches may be required.

- Permitting requirements and designation of capacity use areas may be limited management options because they require local initiatives which are often slow to develop and permit requirements are limited to a few classes of users (Chapter 5.3.2).

- Recognition of the need to develop an emergency or crisis management capacity has increased, particularly in response to recent droughts and localized problems (Chapter 4.6).

- Conflicts among municipal, industrial, and agricultural users have increased (Chapter 5.3.5). This suggests the potential need for state intervention to resolve conflicts.

- Resolving conflicts about ground water use is often limited to the courts, which create case-by-case solutions based on historical precedent. This restricts comprehensive management and anticipatory planning (Chapter 5.3).

- In some states, ground water quality protectin is limited to regulating key point sources. Management approaches which combine R&D, technical capacity, and administrative management capacity are being considered by many states (Chapter 4.6).

- Local governments often are restricted in their ability to manage ground water quality because of lack of information and professional expertise (Chapter 5.3.3).

There are many potential solutions to these problems, includin a variety of water quality control options (Chapter 6), public and private sector water availability options (Chapter 7), and land us management (Chapter 8). Each of these potential solutions raise questions about state legal and institutional structures and their relationship to management strategies. The focus of this chapter is on state and local institutional options which can enhance the capacity to manage ground water. Some attention will be given to specific management strategies which can be used with various institutional approaches. More direct treatment of management alternatives is found in chapters 6, 7, and 8.

This chapter has three specific purposes:

- To identify and describe options which could be used to upgrade institutional capacity for ground water management;

- To summarize the experiences of several states which have used these options; and

- To discuss issues associated with these options.

As shown in Table 9-1, two categories of options are discussed (1) options to improve the organizational capacity to manage groun water; and (2) alternative regulatory models.

TABLE 9-1: STATE AND LOCAL INSTITUTIONAL DEVELOPMENT OPTIONS

General Approach	Specific Option
9.2 Options to Improve Institutional Capacity	1. Integration of ground water quality and availability
	2. Conjunctive use
	3. Emergency response capacity
	4. Critical use areas
	5. Cooperative supply systems
9.3 Alternative Regulatory Models	6. Arizona Model
	7. Nebraska Model
	8. Florida Model

The first category includes five specific options which can be used by state or local governments to respond to ground water problems. While they all can be used to improve organizational capacity, they range from very strong and formal approaches to largely voluntary approaches. For example, integrating ground water quality and availability management requires either reorganization or the creation of a new agency which would have comprehensive responsibility for controlling the resource. A second option, conjunctive use, would probably require reorganization in order to integrate surface water and ground water management. A third option, developing an emergency response capacity, addresses the ability of states to anticipate emerging problems and respond to crises situations. A fourth option, critical use areas, can be used to designate areas of particular concern or to allow for a gradual application of management tools as problems increase. The fifth option, cooperative supply systems, is the most voluntary option in this category; it is intended to facilitate cooperation among public and private sector suppliers of water.

The second category of options addresses comprehensive frameworks for managing ground water resources. Three models are evaluated based on experiences in Arizona, Nebraska, and Florida. Each model combines legal, administrative, and management tools, but with varying degrees of centralization. The Arizona Model concentrates responsbiility in one powerful state organization. The Nebraska Model emphasizes local control of ground water planning and management. The Florida Model represents a mixture of the previous two--responsibility is shared between a state agency and several water management districts. Several of the options discussed in Section 9.2 could be used in any of these three broad administrative frameworks.

9.2 OPTIONS TO IMPROVE INSTITUTIONAL CAPACITY

9.2.1 An Overview of Capacity-Building

States can do many things to improve their institutional capacity to manage ground water. As suggested in Table 9-2, capacity-building can include at least five major functions:

- Problem awareness;
- Informational and research capacity;
- Goal and priority-setting;
- Emergency response programs; and
- Administrative capability.

Ground water management begins with an awareness that problems exist and an understanding of how problems could affect both growth and environmental quality in a state. This includes two central questions: (1) whether ground water has been placed on the political agenda, including attention by legislators and governors, formation of special commissions, etc. and (2) the extent of public discussion and interest in ground water, including the general public and specialized publics such as interest groups and industries. Once awareness and interest have developed, a second management need is to develop informational capacity. This includes knowledge of the characteristics of ground water systems, relationships between ground and surface waters, identification of potential threats to ground water quality such as hazardous wastes or septic tank usage, development of monitoring capacity, and development of state supported research programs. Most southeastern states are now developing ground water information systems, often in conjunction with the U.S. Geological Survey and other federal agencies.

Awareness and expertise are prerequisites to developing a management capacity. Effectiveness of state programs will also depend on the development of specific goals to protect and preserve ground water (such as safe yield or nondegradation), the ability to handle

TABLE 9-2: ELEMENTS OF STATE GROUND WATER MANAGEMENT

I. Awareness of Ground Water Problems

- A. Is ground water management viewed as a state priority?
- B. Has ground water been specifically defined in state environmental statutes?
- C. What is the extent of public discussion or education about ground water issues?

II. Information Capacity

- A. Have ground water resources been adequately defined and characterized?
- B. Are procedures developed for monitoring ground water resources?
- C. Are there specific ground water research programs within the state?
- D. Does the state have a long-range planning capacity which includes concerns for ground water resources?

III. Existence of Ground Water Goals and Priorities

- A. Is there an explicit policy which identifies goals and objectives of ground water management?
- B. Have ground water standards been adopted?
- C. Are standards currently under consideration in the state?
- D. Are critical ground water areas designated?

IV. Emergency Capacity

- A. Do states have an inventory or site log of potential contamination sources?
- B. Do any programs exist for handling emergency waste spills or other ground water pollution accidents?
- C. Have clean-up procedures been specified, including funding, notification, evacuation, and compensation?
- D. Do states hve a drought response capacity?

V. Administrative Capacity

- A. Administrative Responsibility
  - 1. How fragmented are administrative responsibilities?
  - 2. Is there a planning component specified?
  - 3. Is there a program evaluation capacity?
  - 4. What is the commitment of financial and personnel resources for implementation and enforcement?
- B. Coordination and Integration of Programs
  - 1. Are there any mechanisms for coordinating federal, state, regional, and local agencies?
  - 2. Are there any mechansims for coordinating program responsibilities (RCRA, TSCA, SDWA, UIC, etc.)?
  - 3. Is there a capacity for conjunctive management of surface and ground water? for integrating use and quality?
  - 4. Are administrative procedures flexible enough to account for regional differences and to allow for continuous modifications of programs?

emergencies such as contamination of drinking water supplies, and the development of administrative resources. This section discusses options for developing priorities, emergency response capacities, and institutional capacity. The first two sections discuss two of the more comprehensive choices for capacity-building--reorganization to integrate quality and availability management, and conjunctive use management. This is followed by a discussion of two more specific, programmatic activities which would allow states and localities to better respond to emerging problems--development of emergency response capacity and critical use areas. The section concludes with an option which requires an increased local role, cooperative supply systems.

9.2.2 Integrating Ground Water Quality and Availability

A. Description

Traditionally, managing ground water availability has been treated as a separate governmental function from managing ground water quality. A major reason for this is that problems have developed gradually and distinctively, resulting in independent legal and regulatory systems for each. Legal doctrines and common law principles related to ground water use were almost entirely devoted to protecting the rights of individual users. Policies to protect the quality of ground water resources have been a relatively recent phenomena and, in the Southeast, have emphasized the control of specific point sources of pollution which could harm human health. Thus, it has been natural for administration of ground water quality to be separate from ground water availability.

Recently, as ground water problems have increased attention has been given to integrating quality and availability concerns in order to develop better information about the resources and to enhance management capacity. The relationships between ground water quality and availability are crucial in developing problem-solving approaches. For example, ground water overdraft along the Atlantic coast has led to saltwater intrusion (see Section 5.2.2), contaminating drinking water supplies. One option for improving the coordination of ground water management is to integrate availability and ground water protection functions.

Various mechanisms may be used to integrate ground water quality and availability. The most comprehensive would be to create a new agency, such as a Department of Water Resources, or to combine in an existing agency all ground water programs and responsibilities. A second strategy would be to create interagency coordination mechanisms, such as interagency committees or advisory boards, to increase communication, direct research efforts, etc. Such coordination mechanisms could be organized around specific problems (drinking water, overdraft) or on a geographical basis (ground water basins, critical use areas). Reorganization of ground water functions into a single agency will be addressed below.[1]

B. Current Status

According to a survey completed by the U.S. Water Resources Council (1981 Section V), water resources are managed by multiple agencies in most states with use management administratively separated from quality protection. This appears to be less the case in the southeastern states than for the U.S. in general (see Table 9-3). While some fragmentation does exist, several states have moved to a more centralized approach. Georgia and Kentucky each have one agency, a Department of Natural Resources, responsible for both use and quality management. Alabama has recently created a Department of Environmental Management, which incorporates the responsibilities of several agencies. Except for several data collection activities conducted by the Geological Survey of Alabama, the Department of Environmental Management has virtually all of the ground water management authority. While Florida grants use management authority to substate water districts and quality management authority to one centralized state agency, the state can not be characterized as having a fragmented approach to water resource planning (see Section 9.3.3). No southeastern state has more than two state agencies with major ground water authority, and the general trend appears to centralize rather than fragment administrative responsibility.

Georgia is the only southeastern state which integrates all surface and ground water management authority in a single agency--the Environmental Protection Division of the Department of Natural Resources.[2] In addition, Georgia has adopted a one-stop permitting process both to facilitate industrial siting and to coordinate environmental protection strategies. This approach is similar to those adopted by New Jersey, New York, and Wisconsin (Kundell and Breman 1982, 61). The Environmental Protection Division has been assigned water quality functions previously existing in the Department of Mines, Department of Health, and State Water Quality Control Board. It has also been assigned water use management authority which is primarily the authority to issue permits for withdrawals in excess of 100,000 gallons per day.

---

[1] For a brief discussion of nonorganizational coordination techniques, such as advisory committees and coordinating councils, see Council of State Governments (1975, 55-74, and Seidman 1975, Chapter 7).

[2] This approach began with the passage of the Executive Reorganization Act of 1972 and the Ground Water Use Act of 1972.

TABLE 9-3: ADMINISTRATIVE RESPONSIBILITY FOR GROUND WATER MANAGEMENT

Function	Alabama	Florida	Georgia	Kentucky	Mississippi	North Carolina	South Carolina	Tennessee
Use Management								
1. Program development and implementation - Planning - Permitting - Implementation - Monitoring - Enforcement	Alabama Dept. of Environmental Management	Water Management Districts	Department of Natural Resources - Environmental Protection Division	Department of Natural Resources - Bureau of Environmental Protection	Board of Water Commissioners Department of Natural Resources	Department of Natural Resources and Community Development - Environmental Management Commission	Water Resources Commission	Department of Conservation Department of Public Health
2. Data collection and research	Geological Survey of Alabama							
Quality Management								
1. Regulate surface activities	Alabama Dept. of Environmental Management	Department of Environmental Regulation	Environmental Protection Division	Department of Natural Resources	Department of Natural Resources	Department of Natural Resources and Community Development	Department of Health and Environmental Control	Department of Public Health
2. Drinking water control					State Board of Health	Department of Human Resources		

Source: U.S. Water Resources Council 1981.

The purpose of this integrated approach is to take a positive rather than a reactive approach to water resource management and to remove organizational barriers to management (Ledbetter 1980, 33; Kundell and Breman 1982, 21).

C. Advantages

A primary advantage of developing a single ground water agency is that recognition of the inherent linkages among natural systems can be incorporated in the administrative system. Such an administrative system, which reflects a holistic perspective towards ground water, could force more explicit consideration of the need to balance growth values with environmental protection values. Growth pressures often are reflected in increased demands for water resources while environmental values are reflected in water quality considerations. Under a single agency, compromises between growth and environmental values would develop at the administrative level--an advantage over the traditional model, in which different values are represented in separate agencies.

Administratively, this option could improve the coordination of use and quality management. The review of state ground water management by the U.S. Water Resources Council (1981) found that many states have multiple agencies involved in ground water administration--including water resource boards, departments of health, departments of human services, departments of conservation, pollution control agencies, etc. Fragmentation of administrative responsibility was partially caused by the growth of federal grants-in-aid over the last 20 years which created an incentive for states to develop single-purpose agencies. In addition to making interagency coordination more difficult, this has created lines of political control between single-purpose state agencies and federal agencies, rather than among state agencies and state executive and legislative bodies (Council of State Governments 1975). Consolidation of ground water programs in one agency could strengthen state control over this resource at the executive level, through reducing the occurrence of conflicting goals and programs, avoiding duplication, and gradually creating stronger constituencies organized around one resource (Miles 1977; Arnold 1974).

Administrative consolidation and coordination could be particularly advantageous in reducing the uncertainties and delays associated in obtaining rights, use permits, or siting permits. For example, Georgia's one-stop permitting process facilitates siting since a prospective user knows exactly what environmental requirements are expected. Delays, confrontations, and siting errors can be avoided, industrial pollution control can be enhanced, and industrial growth can be facilitated.

An important concern with any new management approach is economic cost, particularly as states have faced increased financial stress and the probability of assuming responsibility for many programs previously financed at the federal level. It is difficult to develop a comprehensive picture of the costs of various management approaches, which depend on personnel commitments, specific management tools, and enforcement levels. However, one recent estimate of per capita expenditures on water management indicates that Georgia's statewide approach requires less money to administer ($.45 per capita) than the approaches used in three other southeastern states--Florida ($.98), North Carolina ($.97), and South Carolina ($1.32) (Kundell and Breman 1982, 53). Of course, these data may also indicate a state's commitment to water resource management and they do not provide a comparison of the effectiveness of state programs in meeting their goals.

D. Disadvantages

Potential disadvantages with integration of ground water quality and availability are: (1) concerns over the balance between environmental goals and industrial growth; (2) participation by various interests; and (3) the extent of management controls. Separation of quality and availability management is viewed as desirable by some environmental protection interests in order to help ensure that each of these values are adequately represented. That is, environmental values might receive greater support and emphasis if administered separately rather than made part of a general water resources agency. In states with strong water development agencies, a potential concern over an integrated system is that goals to make water available for various users--for example, to encourage new industries--could supercede goals of protecting the resource. However, separation of functions is not always supported by environmental groups. For example, Georgia's integrated statewide water management approach has been supported by the Georgia Conservancy, the major statewide environmental organization (Kundell 1983). And in South Carolina, the Wildlife Federation has actively sought increased integration of water resource planning at the state level (South Carolina Wildlife Federation 1981).

A second concern with integrated and centralized approaches is whether local groups will participate in water resource planning and management. In many states which have centralized administrative systems, this issue has been very important. For example, during the development of Arizona's Ground Water Use Act of 1980, the degree of local control was one of the most significant issues faced in the formation of the policy (see Section 9.3). Participation also appears to be a concern in Georgia; the major trade-off is economic, since participation can be increased by developing regional (substate) and local mechanisms but with a substantial increase in per capita expenditures for water management (Kundell and Breman 1982, 53, 72).

A third concern is the availability and strength of specific management tools. That is, while integration of functions may be a very valuable approach, overall program effectiveness also depends on the strength of management tools and the financial support for using them. In the Georgia case, Kundell and Breman (1982, 65-66) suggest that effectiveness of water management can be improved by increasing state financial expenditures and by including agriculture in the permitting process. Exemption of this major user--accounting for 380 mgd use or 33 percent of total ground water use--"greatly reduces program effectiveness" (Kundell and Breman 1982, 65).

E. Feasibility

In general, administrative reorganization is a difficult political process because it alters existing relationships among executive agencies, legislative committees, and public constituencies. These relationships are particularly strong in water resource policy; in many southeastern states the need to improve management and administrative capacity is well-recognized in the management agencies but is frequently resisted by current water users. Regarding ground water quality and availability management, administrative separation reflects historical factors which develop considerable inertia. However, much change has occured in the past decade, including increased stress on water resources, increased competition, and increased recognition of the need to improve management capacity. These changes are reflected in the number of southeastern states which have taken a stronger role in ground water administration.

Thus, the appropriateness of integrated management will vary considerably across the Southeast, according to the problems, the historical development of water policy, and the extent to which new pressures for ground water use are felt in the state. Georgia, has developed an administrative approach which integrates surface and ground water management and quality and use management. This administrative system, which has been commended by a variety of parties-at-interest, should serve as a useful model for many other states.

9.2.3 Conjunctive Use

A. Description

In most areas, surface and ground waters are related; as demands and threats to water resources have increased, pressures to manage them conjunctively have also increased. However, "conjunctive use management" is interpreted quite differently from state to state, ranging from narrow definitions of making both sources available for use, to broader, management-oriented definitions.

For this report, conjunctive use management refers to the integration of surface and ground water use to provide a more reliable and efficient supply system and to the development of active management programs to preserve and protect water resources.

Depending on the existing legal and institutional structure, establishing conjunctive use might require either legislative action or administrative reorganization to consolidate surface and ground water programs into the same agency. An important element of the legal structure would be to apply the same law to both ground and surface water sources in areas in which they are so closely interconnected that using one effects the other (Trelease 1982). The U.S. National Water Commission (1973, 233-38) recommended that both sources should be integrated and managed conjunctively; "the law of waters should be a single, integrated body of jurisprudence."

Conjunctive ground and surface water use is limited to areas where both sources are accessible and of appropriate quality, unless more drastic measures such as water importation are being considered. In some areas, the opportunity to use ground water in conjunction with surface water exists where larger perennial streams are underlain by permeable alluvial aquifers and this provides for more uniform year-round supplies without reservoir construction (U.S. Geological Survey 1974). For this reason, conjunctive management can be practiced by local, as well as state, governments. For example, the city of Huntsville, Alabama, draws its water supply from five wells in combination with Tennessee River water (Cobb 1981).

Several management tools can be used to enhance conjunctive use, including: designation of critical use areas, retiring of water rights, augmentation, and the use of saline aquifers for water storage. Considerable attention also has been given to development of mathematical models to allocate ground and surface water in conjunctive use systems. However, these models are constrained by their substantial data requirements (Maknoon and Burges 1978).

B. Current Status

Much of the experience with conjunctive management comes from the West. In New Mexico, underground water basins were declared critical areas and their management was brought under the control of the state engineer. If withdrawals adversely affect stream flows, retirement of surface rights must be used to offset continued withdrawals. In California, ground water management districts have been formed by court order to regulate withdrawals and use. Colorado allows ground water users in a given area to devise any plan that will guarantee water to senior surface water users (e.g., reservoir purchase) as long as it is acceptable to state water officials and surface water users. The augmentation plan is then carried out by a private voluntary organization. If no plan is devised, the rules of the state engineer regulate ground water users' pumping time (U.S. Water Resources Council 1981). Arizona consolidated surface and ground water management into its Department of Water Resources as part of its Ground Water Act of 1980.

Conjunctive management has been emphasized more in the western states than in others because of water scarcity and similar allocation procedures for both surface and ground water. As water supply problems have developed in other regions, conjunctive management has received more attention in state planning agencies, for example in Florida and North Carolina (U.S. Water Resources Council 1981). North Carolina uses conjunctive management in capacity use areas and Florida emphasizes conjunctive management by local water management districts. However, in many states water laws continue to reflect the myth that ground water is separate from and unrelated to surface water (U.S. National Water Commission 1973). Even states which have some conjunctive management have been criticized for not using it. According to Peek (1981), conjunctive management has received little attention in North Carolina to date.

C. Advantages

Conjunctive use management will help to increase recognition of the relationship between surface and ground water and to develop consistent approaches for dealing with both sources. Conjuncitve management facilitates increased attention to the impacts which the use of one has on the other and the development of programs to mitigate adverse effects.

With conjunctive use, more efficient use of water resources can be obtained, water resources planning can be improved, surface storage and distribution requirements can be decreased, and conservation can be increased (Maknoon and Burges 1978). The dangers of severely depleting a vital water source are avoided when the use of multiple sources is well-planned. During periods of low surface flow, which very often coincide with peak seasonal demand, ground water can be used to augment surface water; during peak runoff periods artificial recharge techniques can be used to increase ground water supplies for use during dry periods (U.S. Geological Survey 1974).[1] Access to two water sources can also allow for a shutdown of one, if problems arise, with lessened impacts on overall supply (Cobb 1981).

---

[1] For an elaboration of augmentation options, see sections 7.3.4 and 7.3.5.

D. Disadvantages

Creating the necessary information base for conjunctive use may be an important barrier. For modeling purposes, data requirements can be extensive and costly (Maknoon and Burges 1978). Also, conjunctive use is not a simple technical management adjustment--it is closely tied to legal, economic, political, and physical factors. Since conjunctive use is likely to be most important where ground and surface water connections exist, tracing the effects of one source upon another is critical to effective conjunctive management; this task appears to be difficult, if not impossible, in some areas (Trelease 1982). Further, legal questions about rights and allocations can restrict conjunctive management, particularly since separate legal doctrines have a long history in most states.

E. Feasibility

In their survey of state water management institutions, the U.S. Water Resources Council (1981) found 21 states which had adopted or were considering some form of conjunctive use. For most of these states, conjunctive use means considering ground and surface water together and to use them to increase the reliability of supply. This somewhat narrow definition of conjunctive use appears to be increasingly feasible in the Southeast.

A broader definition of conjunctive use is to consider it an active management strategy designed to preserve and protect water resources. This type of conjunctive use management will face several barriers. First, the general lack of public awareness about ground water problems means that there is likely to be little pressure to pass new legislation or create new agencies. Secondly, the historical legal system which has separated surface and ground water law will make it difficult to integrate the two. Thirdly, conjunctive use, similar to any active management approach, is likely to be resisted in some areas of the Southeast which view water largely as an individual right.

9.2.4 Emergency Response Capacity: Water Shortages

A. Description

Water shortage emergencies can result from droughts which develop over several months, contamination of ground or surface water, long-term overuse of supplies, and inadequate water management. Because of the historical abundance of water in the Southeast and the lack of awareness by the general public about water resource issues, developing the capacity to respond to water shortages has not received adequate attention (Peek 1981, 57). For much of the Southeast, building the capacity to handle water shortage emergencies will require enhanced planning, management, and administrative capacity.

Managing water shortages can be divided into two activities: improving long-term management and creating short-term emergency response plans. Longer term activities, which can be part of an active water management program, include planning for future water demands and developing water supply projects, such as construction of surface impoundments or drilling wells. Another feature of managing water shortages is to improve the quality and accessibility of information about water resources. Industrial, agricultural, and urban water users need this information to adequately anticipate future conditions.

Even with active water management, shortages can still occur. One option for reducing the impacts of shortages is to develop emergency response plans. The two most crucial features of such a plan are overall flexibility and the establishment of "trigger mechanisms." Flexibility is important because many uncertainties are associated with emergency shortages, including the extent of public cooperation, the length of the shortage, and the extent of cooperation by well owners. Trigger mechanisms are preassigned water shortage indicators or contamination indicators that would automatically initiate emergency plans if certain levels were reached. The threshold levels would be determined regionally based upon the characteristics of each area--ground water recharge rates, overall supplies, rainfall, and water usage.

B. Current Status

Several southeastern states have recognized the need to develop the capacity to manage water shortages: North Carolina, South Carolina, Georgia, Mississippi, and Florida. Florida has the most highly developed water management system of which emergency water shortage plans are a part. For example, the water shortage plan of the South Florida Water Management District adopted in May of 1982 identifies specific actions for declaring a shortage and establishes emergency restrictions, monitoring, and enforcement mechanisms. In addition, it establishes criteria for different shortage levels and for usage classification. Specific restrictions on water use are then based upon the declared water shortage phase and the classification of the use. For instance, in Phase III (extreme shortage) uses that are classified as aesthetic (fountains, waterfalls, etc.) are prohibited. Information about the plan has been made available to the public via the media and the Water Management Bulletin published and distributed by the South Florida Water Management District.

In Georgia, a permitting system has been established. Currently it serves as a data source about water use, but in an emergency it could be used to curtail water use. Permits are classified into six priorities. Within a class, prior permitholders have first rights to the water during shortages. A proportionally restrictive permitting system could also be used during an emergency. The state water law includes provisions for local authorities to develop water shortage plans, but no situations have yet occurred where such measures have been viewed to be necessary (Atlanta Regional Commission 1980, 7-8).

The Governor's State Water Law Review Committee of South Carolina recently recommended that the Water Resource Commission design and coordinate the development of a water shortage response plan. Currently, the Governor is only allowed to restrict water use for a maximum of 15 days and the Water Resource Commission is allowed to expand its regulation of water use during an emergency only to provide information and advice to the Governor (South Carolina. Governor's State Water Law Review Committee 1982).

C. Advantages

Advance preparation for emergency water shortages rather than ad hoc response can help to minimize economic costs and social and political conflicts. In addition, developing a response to potential water shortages can provide other benefits, including information development about water resource characteristics and reassurance to users that contingency plans exist and their needs have been equitably considered. (Specific options for developing adequate supplies are discussed in Section 7.3). The cost of being unprepared can be very high: to help relieve the droughts in 1977 and 1978, the Federal Government spent over 844 million dollars in more than 3,000 counties, and even this was considered inadequate by many (Western Governors' Policy Office 1978).

An assured supply of water is especially important to industrial and agricultural users. Many industrial processes require consistent water input. Sites with response plans that make this a high priority are likely to interest prospective companies. Agricultural users can not afford sudden water shortages. Robie (1978, 65) estimated that in 1977 the California ranchers, dairymen, and crop growers lost 800 million dollars because of water shortages. Had measures been taken sooner to mitigate the effects of the drought, their losses could have been cut. A public that is aware in advance of the consequences of its use patterns and has been educated about the need for restrictions during emergencies is more likely to comply with voluntary cutbacks and accept mandatory restrictions without undue resistance (Blackburn 1978; Griffith 1978; Woo 1982).

D. Disadvantages

Since many states do not have well-developed management capabilities, financial and personnel resources may be required to build an emergency response capability (Atlanta Regional Commission 1980, 8). Information about past droughts, ground water levels, recharge rates, and use patterns is necessary to properly establish trigger mechanisms, severity classes for shortages, and use restriction standards; yet, it may be very difficult to obtain this information. Without an enforcement capacity, any plan that restricts water use is not likely to be effective. In Missouri, of 32 municipal water utilities that requested cutbacks in consumption the 6 that did not achieve compliance were those that had voluntary programs or inadequate enforcement (Reed 1982, 123).

Often, there is a shortage of trained personnel in this field (U.S. Water Resources Council 1981). Until a crisis arises in a given region, the issue does not get much attention. Emergency response management is much easier to develop within the context of active water resource managment including ground water. For each state in the Southeast the regulatory responsibility for these activities varies; assigning the responsibility for developing a response plan should take into account those institutional frameworks.

E. Feasibility

As is true for most approaches to increasing the state role in managing water resources, developing an emergency response capacity will be impeded by a lack of public and political support. Since many states are currently experiencing only localized problems and because water resources have been so abundant historically, there will be some resistance to planning for circumstances which appear to occur infrequently.

In spite of these continuing barriers, there are many reasons to suggest that developing an emergency response capacity is an attractive option to many states. The recent drought experiences in Georiga, Florida, and South Carolina increased public awareness about impacts of water shortages. Because so much of the region is enjoying economic growth, recognition of the importance of reliable water supplies to attracting new development and retaining existing economic activity has increased. Developing an emergency response capacity is also easier than developing many capacity-building options, since it can be accomplished within existing institutional frameworks and has relatively small personnel and financial requirements.

9.2.5 Critical Use Areas

A. Description

A critical (or capacity) use area is one in which the uses of surface and ground water have developed to a level that threatens the capacity of the resource to renew itself. Threats to the ground water resources could include droughts, overpumping, or water quality degradation. The goal of public intervention in such an area would be to protect the interests of property owners and the public interest through coordination and regulation of ground water practices. Regulation could include controls on the timing and rate of withdrawals, well depth and spacing requirements, land use management, and restrictions on new wells.

The state water resources agency usually is responsible for studying the area and developing strategies for management of the water resources in a way which would stabilize or improve the situation. When the desired conditions have been reached, the state agency could remove the capacity use designation and return responsibility for management to the state's normal ground water management framework.

B. Current Status

In the Southeast, Florida, North and South Carolina, and Mississippi have legislation authorizing this approach.[1] North Carolina declared a capacity use area in 1968 in a phosphate mining area in the east-central part of the state. South Carolina now has two such areas--in the Myrtle Beach-Grand Strand area and the Low Country near Savannah, Georgia. A third near Charleston, South Carolina is under consideration. All five states use a permit system as the major regulatory approach to management.[2] Mississippi's Groundwater Management Act (1976) authorized the declaration of capacity use areas and the correlation of surface and ground water uses in managing these areas. In contrast to other states, in South Carolina a capacity use designation can be made only upon request to the state from a local area and after studies have documented the need for management.

Twenty other states outside the study area have also taken the capacity use area approach (U.S. Water Resources Council 1981, p III 4-13). For example, Virginia's Ground Water Act of 1973 declared control of ground water resources essential to the public interest and provided regulatory measures applicable to geographically restricted areas with identified ground water management problems. Virginia's regulations, as do those of most states, focus primarily on new users. However, they do provide for state review of existing uses against the principle of beneficial use. Arizona and Nebraska laws also authorize the designation of special control areas in which ground water withdrawals may be regulated through cutbacks in production, rotation of pumping, refusal of permits, etc. (Kyl 1982; Clark and Arguedas 1978). Unlike the Arizona centralized approach to management of critical use areas in which the state government has a strong role, Nebraska takes a more decentralized approach in which local interests have a stronger role (see Section 9.3).

---

[1] Georgia previously had legislation authorizing this approach, but 1973 amendments to the state's Ground Water Use Act extended the jurisdiction of the Environmental Protection Division to an state wide basis. Thus capacity use areas were obviated.

[2] See Section 7.2.2 for a discussion of permitting systems.

C. Advantages

Managing specific regions or areas provides states an opportunity to develop unique strategies which are technically suited for the problem and also respond to the regional or local values at stake. It also allows the state government to intervene in a limited area on a short-term or long-term basis depending on the particular problem rather than imposing a uniform statewide management program. This is particularly important for states like South Carolina or Alabama which typically have sufficient water supplies of adequate quality but are subject to localized shortages caused by droughts or rapid growth in demand.

D. Disadvantages

The most difficult part of applying this type of management is the time required to study an area in order to develop location or problem-specific solutions. Ideally states should identify potential problem areas and intervene before problems become severe. However, in some states, information about supplies and uses may not be adequate for anticipating such problem sites.

If used by itself without more comprehensive planning, capacity use designation could encourage a crisis-management approach rather than active management or long-term planning (Sherwani 1980). In fact, designation of capacity use areas may be a politically accepted approach which is used to avoid development of more direct management capacity. The capacity use approach has not been very successful in the Southeast (Howells 1980, 8); for example, it was tried and eliminated from Georgia's water management approach. It has also been criticized as a barrier to the development of more integrated and comprehensive management approaches (Kundell and Breman 1982, 57).

Attempts to deal with water allocation problems in North Carolina by developing capacity-use areas have met with limited success. Criticisms of the state's effort include misunderstandings regarding what the Water Use Act would allow the state to do, lack of adequate information on which to base strict enforcement of the regulations, and lack of adequate staff with well-defined responsibilities for implementation (Hufschmidt and Stevens 1978). For example, the Water Use Act was not clear about whether or not compensation would have to be made to users who had to reduce or discontinue withdrawals. Other uncertainties associated with the Act include the impact of riparian principles on such issues as determining "reasonable" uses and in allowing water transfers from the capacity use areas (Hutschmidt and Stevens 1978).

Designation of capacity use areas is one of the most politically feasible ground water management approaches; as evidenced by its adoption in four southeastern states and 20 other states nationwide. In part, it represents a first-step in controlling ground water problems. However, it is also a reactive approach which essentially ignores the need to anticipate emerging problems. Because it represents a case-by-case or area-by-area approach, it is likely to be a barrier to more comprehensive and integrated approaches. Use of this approach in the Southeast has received largely negative evaluations.

9.2.6 Cooperative Supply Systems

A. Description

Cooperative supply systems are designed to enhance water availability by increasing cooperation among water supply utilities and improving the infrastructure supplying water. Cooperative supply systems may be instituted through informal agreements among districts or by unification and consolidation. As currently practiced, they include a direct state role in their development and financing. Cooperative supply systems are particularly suited to reducing imbalances between the location of water resources and the needs of consumers, reducing inequities in financial resources among water districts, minimizing territorial conflicts over jurisdiction, and improving the distribution of water and equipment.

Similar problems are experienced with sewer districts, particularly when treatment capacity is inadequate because of small community size. Cooperation or consolidation of sewer and water districts improves financial resources and can contribute to more coordinated growth management. Improved service consolidation of sewer systems can also reduce problems such as excessive septic tank density or siting septic tanks in poor soils (see sections 4.3 and 6.2). Although the discussion below focuses on water supply system regionalization, unification for sewer districts has similar advantages.

Unconsolidated multidistrict regions, which characterize most of the Southeast, contribute to over-reliance on ground water because little cooperation typically exists to achieve common sources of surface supply or to develop water transfer and treatment projects. Small autonomous districts also frequently rely on ground water aquifers of immediate proximity with low development costs. Since water self-sufficiency is an important goal for most water districts, ground water is viewed as a desirable source of supply. Even when water demand increases or shortages occur, these districts frequently search for new sources of local ground water to protect their autonomy. Thus, individual supply systems can contribute to ground water overuse.

The Safe Drinking Water Act of 1974 promotes cooperation among local districts, or regionalization, as a potential solution to an area's water supply problems. Regionalization is the integration of the services and administrative structures of two or more independent utilities. The Regionalization Committee of the American Water Works Association has defined regionalization as:

(1) Consolidating administrative elements of several utilities into one contractual administrative organization having the sole responsibility for managing and operating the water supply system;

(2) A coordinated, physical integration of two or more systems for the purpose of using the common water resources to provide service to the system's combined areas; and

(3) The appointment of a policy board to provide uniform water services for two or more water systems which could set standards applicable to all of the utilities involved.

B. Current Status

Cooperative supply receives considerable attention among water utilities. A survey by the American Water Works Association (1979b) indicates that about 25 to 70 percent of responding southeastern utilities have studied regionalization (see Table 9-4). Primary examples of the development of cooperative supply systems in the Southeast are found in south Florida. In Broward County, there are 52 municipal and investor-owned water supply systems, all dependent on the Biscayne Aquifer. The Broward County comprehensive plan recommends consolidation of the 25 smaller utilities into the 27 larger utilities. Regionalization is viewed as a basis to manage saltwater intrusion and encourage the development of interconnections to provide efficient system use in emergency situations (Broward County Planning Council 1981).

In Dade County, 15 separate systems exist with wells and treatment facilities. The Miami-Dade Water and Sewer Authority provides

TABLE 9-4: INTEREST IN REGIONALIZATION AMONG SOUTHEASTERN STATES

State (Questionnaires responses/ recipients)	Utilities studying or involved in regionalization	Most common factors presenting obstacles to regionalization (rank order)
Alabama (0/2)	--	--
Florida (33/177)	9	(1) Conflict in organization or institutional structure. (2) Unwillingness to one utility to assume inadequacies of anothers system. (3) Incompatible system design.
Georgia	1	Problems with definite future service areas.
Kentucky (3/31)	1	(1) Unwillingness of one utility to assume inadequacies of others system. (2) Historical antagonisms toward neighboring utility.
Mississippi (27/104)	9	(1) Communities desire total independence. (2) Unwillingness to communicate.
North Carolina (8/36)	2	None identified
South Carolina (14/36)	10	(1) Unwillingness of one utility to assume inadequacies of others system. (2) Communication problem. (3) Fear of big government.
Tennessee (7/47)	2	(1) Fear of big government. (2) Historical community antagonism.

Source: Adopted from American Water Works Association 1979b.

most of the water, about 200 million gallons daily, either directly or through contracts to other utilities (Metropolitan Dade County Planning Department 1979). A significant degree of regionalization has already occurred in Dade County, and the Water and Sewer Authority continues to assimilate smaller districts and acquire their treatment plants (Day and Zimmerman 1982).

Another example of district consolidation is in New Castle County, Delaware. Because of rapid growth, three small utilities interconnected supply lines with the larger community that had excess capacity. The result is expected to be a major savings in capital expenses. The consolidation required numerous compromises among companies about water rate charges and the expansion of the competitive service area (Hurd 1979).

C. Advantages

A decade ago there were about 30,000 water utilities in the U.S., of which about 6,000 were investor owned. About 14,000 of the utilities served rural areas. In 1973, the first National Water Commission recognized the need to coordinate planning among water supply systems because of the proliferation of new small water supply systems. As metropolitan areas expanded, new systems were installed on the fringe areas. Such proliferation can result in several problems (National Water Commission 1973):

(1) Inadequate and unnecessarily costly service;

(2) Poor integration of water supply with planning;

(3) Inability to finance new growth; and

(4) Encroachment of urbanization on watersheds.

Uncoordinated management by many cities is, perhaps, an even larger problem. Pumping ground water can result in unplanned depletion of supplies (National Water Commission 1973, 444). In the Southeast this pattern of development has occurred in the Myrtle Beach, South Carolina area and the Savannah, Georgia area. The Commission recognized that

> consolidation of the performance of one or more separate tasks in a single water service district throughout a metropolitan area, or some significant portion of it may yield economies of scale that have not heretofore been captured by individual cities in districts pursuing separate courses (National Water Commission 1973, 443.)

In addition to economies of scale, administrative efficiency and service delivery improvements can result (American Water Works Association 1979). For example, centralized meter reading, billing, and purchasing services have been implemented in Broward County (Broward County Planning Department 1981). New water supplies also can be tapped when system size permits larger revenues or bond issues. This size advantage can enhance the financial capability to shift from reliance on ground water to use of surface water. This is occurring in New Brunswick County, North Carolina, where the county entered a cooperative financial arrangement with the City of Wilmington to develop surface water from the Cape Fear River (Brunswick County Planning Department 1980).

D. Disadvantages

Difficulties with cooperative supply systems include: (1) physical design inconsistencies among systems, such as improper pipe sizing or pumping leading to reduced efficiency; (2) personnel reorganization requirements that could place some staff in inappropriate positions; (3) and financial burdens of upgrading an old system (American Water Works Association 1979). In addition, the capital needs of the consolidated system may lessen its fiscal credibility with bond markets or investment circles (Broward County Planning Department 1981).

E. Feasibility

Resistance to this option can be expected from those who favor the autonomy of the single district or utility in order to retain income and disbursement authority. Other factors that contribute to the lack of political acceptability include: local distrust of larger government agencies; financial burdens of obtaining systems in poor condition; and historic social or political conflicts with adjacent areas (Broward County Planning Council, 1981). These constraints often can be overcome as population increases and as crises due to shortages become more frequent.

As reported in the American Water Works Association Survey (see Table 9-4), the most common obstacle to regionalization is the unwillingness of stable and efficient utilities to assume the liability or inadequacies of another utility. Other obstacles include lack of communication, community antagonism, desire for independence, and fear of government (American Water Works Association 1979b).

Many obstacles to regionalization occurred in the New Castle County case discussed above. Of particular importance was the need for companies to reduce planned service area expansion and to agree on equitable rates. In addition special hearings were needed to allow water rights to be transferred among municipalities (Hurd 1979). All of these jurisdictional and legal obstacles create delays or reduce the political feasibility of cooperation among utilities.

While these obstacles can prevent the development of cooperative supply systems in some areas and impede their implementation in others, in general, the future prospects for this option are promising. Several areas in the Southeast have adopted it and this option appears particularly well-suited to responding to localized problems, which are likely to become more pervasive in the region. It is also well-suited to those areas which want to avoid a stronger state role in ground water management.

9.2.7 Summary of Organizational Capacity-Building

Five options pertaining to capacity-building for ground water management have been discussed in this section. These options, representing only a few of the choices open to states and localities have received considerable attention in the Southeast. Further, these are not isolated choices--several could be combined to meet the particular needs of a state or local area.

Several general conditions will influence the extent to which these options are used in the Southeast. Among the most important are:

- The kind and severity of problems faced by the states and their capacity to anticipate emerging conditions;
- Existing institutional capacity: while some southeastern states, such as Florida, have already adopted several of these options, others have relatively undeveloped water management institutions;
- Political conditions: public awareness, interest group activity, and the commitment of legislatures and governors may be necessary to adopt several of these options; and
- Economic and financial conditions: increased financial difficulties in all states will mean that water resource management will compete for resources with many state functions which traditionally are viewed as more important.

Given these general conditions, the following summary makes a few specific comparisons among the five options. These comparisons are summarized in Table 9-5.

A. Advantages of Capacity-Building

Three primary advantages exist for these options to improve state and local management capacity. First, they help to create a more active information-based ground water policy system. In this

TABLE 9-5: SUMMARY: ORGANIZATIONAL CAPACITY-BUILDING

Option	Description	Current Status	Advantages	Disadvantages	Feasibility
• Reorganization to Integrate Use and Quality Management	Ground water use and quality management functions are consolidated into one administrative agency to improve administrative effectiveness.	In the Southeast, only Georgia has an integrated administrative approach. Similar systems exist in New Jersey, New York, and Wisconsin.	• Likely to force more direct consideration of relationships between quality and use. • Fragmentation of management would be reduced. • Executive level control over water and growth would be increased.	• Consolidation could lead to a reduced emphasis on either use or quality management. • Effectiveness will depend on the strength of management tools. • Local participation in ground water management could be reduced.	Several political barriers exist in many states, but this approach is in use in Georgia.
• Conjunctive Use	End legal distinctions between surface and ground waters and consolidate administrative functions into one agency. Management tools include modeling and designating critical use areas.	Widely accepted as a useful management approach (21 states), including Florida, Georgia, and North Carolina. Arizona has consolidated surface and ground water functions into one agency.	• Forces more direct attention to water resource management. • Increases state flexibility to manage water resources while also encouraging new economic development.	• Lack of understanding about complex interrelationships will make implementation more difficult. • Legal issues may surface over the priority of rights.	Feasible in many states as demands for water increase. Adoption will be constrained by historical legal precedents and inherent political difficulties.
• Emergency Response Capability	Develop the organizational capacity to respond to crises, including identification of administrative responsibility, development of plans, and identification of alternative supplies.	Considerable experience exists regarding drought management in the western states. Florida's water management districts have comprehensive drought management plans.	• Considerable time can be saved in responding to a crisis; • A fuller range of options can be considered; • More equitable solutions can be developed.	• The uncertainty of crises situations can make such plans useless; • Because many crises are infrequent, it will be difficult to maintain an expert administrative staff.	Feasible option for many states. This capacity can be built in to existing water planning agencies. The major constraint is "don't fix it until its broke" mentality.

(continued)

TABLE 9-5: (continued)

Option	Description	Current Status	Advantages	Disadvantages	Feasibility
• Critical Use Areas	Designation of specific areas within a state which face particular stress on ground water. Short-term or long-term management strategies would be used in these areas.	Approach is authorized in Florida, North and South Carolina, and Mississippi. Outside the study area, 20 other states have similar approaches.	• Active management strategies are targeted to specific area needs. • Considerable flexibility is allowed for developing different management approaches.	• Developing the necessary information base about a particular area may be quite time-consuming. • This could lead to crisis management without more comprehensive planning efforts. • Effectiveness of approach in the Southeast has been questioned.	Capacity use designations are being adopted increasingly. However, they are only a first step in the development of an active management strategy.
• Cooperative Supply Systems	An ad hoc contractural arrangement for shared water supply. It requires co-ownership of the infrastructure for providing supply and consolidation of utilities.	Consolidation and co-ownership are found in areas of Florida and North Carolina.	• Flexible enough to provide short-term or long-term solutions. • Can have significant economies of scale. • Can be used to increase water supplies.	• Since this option is designed to improve the efficiency of water services, ground water quality issues and active management techniques are not necessarily included. • Physical design deficiences may prohibit coordination.	The major constraints are feared loss of autonomy and potential financial difficulties. However, this option is applicable to some local areas in the Southeast.

regard, they will facilitate a closer consideration of the relationship between water resources and growth policy. All options can be used to reduce administrative fragmentation by increasing cooperation, coordination, or consolidation. Several options, particularly reorganization, capacity use areas, and emergency response capacity, can be used to increase understanding of the relationship between ground water quality and availability.

Secondly, many of these options are anticipatory--they improve the capacity of state or local governments to prepare for emerging conditions. This can be important for both emergency situations, such as contamination of an aquifer, and longer-term developments, such as increased competiton among potential users. Conjunctive use, emergency response and integration of use and quality management are particularly advantageous in this regard.

Thirdly, several options are advantageous regarding implementation. Emergency response, capacity use, and cooperative supply can be targeted to specific circumstances or geographic areas, rather than requiring a uniform, centralized management approach. Since emergency response and critical use can be integrated into existing institutions, they are likely to create less political resistance, which should improve the implementation process.

B. Disadvantages of Capacity-Building

In many respects, the current political climate is not conducive to increased government intervention into activities which have had a large degree of private sector autonomy. This appears to be true at both the federal and state levels. Most of these options will require increased state funding for new staff positions, enforcement, and monitoring. This disadvantage is particularly true for more comprehensive management options such as reorganization and conjunctive use, but also appears to be true for the other options. Except for cooperative supply systems, these options reduce local control and remove administration from the locus of the problem. Without effective mechanisms for state-local coordination, the effectiveness of these options could be reduced.

Many of these disadvantages are less severe for cooperative supply systems, largely because they are considerably less comprehensive in scope, more voluntary, and less threatening to overall state policies. Cooperative supply systems could coexist with several approaches for active state management. However, coopertive supply systems are not designed to provide the active management approach provided by the other options. Thus, key considerations such as ground water quality and development of incentives and sanctions for preservation and protection of ground water are not included.

C. Feasibility for the Southeast

Emergency response capacity, conjunctive use management, and capacity use areas already have received considerable attention in the Southeast, particularly in Florida and North Carolina. Increasing awareness of ground water problems in state executive agencies and increasing economic and population stresses on water resources suggests that these three options are feasible--in fact, they are likely to be used increasingly as a natural consequence of the momentum already developed in several states. Cooperative supply systems are not currently widespread but seem well-suited for the localized supply problems typical in some areas.

Reorganization to integrate quality and use management faces several barriers related to the historical separation of these two functions and resistance to centralized approaches. However, Georgia has developed an integrated approach which appears to be well-suited to the current management needs of the state. As ground water problems increase, the Georgia experience will be useful to many other states.

9.3 ALTERNATIVE REGULATORY MODELS

Several specific options for improving institutional management capacity have been reviewed. A broader set of questions concerns the overall structure and administration of ground water programs. Particularly important questions in this regard concern the level of centralization and relationships between state and local governments. This section discusses three models for state regulation of ground water. The Arizona Model (9.3.1) is a centralized approach which emphasizes comprehensive state control over ground water use. The Nebraska Model (9.3.2) emphasizes localized planning and management with the state providing an overall coordinating role. A mixture of these two approaches is found in the Florida Model (9.3.3), which divides ground water management between a state agency and several localized water management districts.

9.3.1 The Arizona Model

A. Description

In 1980, Arizona enacted what has been called the most comprehensive ground water management system of any western state (Clark 1980). Many factors contributed to the enactment of this system, including the severity of ground water overdraft in Arizona, the history of nonmanagement of water resources and the changing political power base in the state. The stated purpose of the Arizona law is to reduce ground water withdrawals over a 45 year period to a level equal to the recharge of the aquifer; it also has a well-recognized political goal of allowing increased accessibility to ground water by industrial and municipal interests (Kyl 1982; Higdon and Thompson 1980).

The three major features of the Arizona Model are:

- The legal basis: The Ground Water Management Act which establishes the legal and regulatory framework for ground water management;
- The administrative system: The organizational framework for administering ground water, determining state-local relationships, and enforcing the law; and
- Specific management tools: The incentives and sanctions used to promote "safe yield" of ground water resources.

In this section, attention is given to the legal and administrative aspects of the Arizona Model. Most of the management tools used in the model could be used in either centralized or decentralized frameworks. Some of these management tools--including pump taxes, augmentation, and conservation--are elaborated in Chapter 7.

The Arizona Ground Water Act established three major legal concepts (Kyl 1982, 483). The first is the statutory specification of ground water rights--ground water may not be used except as specified under three new categories of rights. Second, the law requires mandatory conservation and state management in areas of the state experiencing the worst problems. Third, the law specifies that ground water will be administered under a new, centralized Department of Water Resources (DWR). It is the authority of the director of the DWR which makes the Arizona Model an almost completely centralized administrative system.

All state level surface and ground water management functions, except for water quality, were consolidated into the new DWR,[1] with the director appointed by the governor. The Act also established four "Active Management Areas" (AMA's) which are similar in concept to critical use areas. The director of each AMA is appointed by the director of the DWR and the activities of each AMA are determined by the director of the DWR. In addition, the director of the DWR has the authority to carry out virtually every substantive provision of the law. The most significant aspects of this authority are: (1) to determine the water rights (or duties) for agricultural users, based on the amount of water deemed necessary for the crops historically grown on that land; (2) to develop specific management plans to reduce water withdrawals in each AMA; and (3) to file civil and criminal penalties for violations of the Act.

---

[1] In this regard, the Arizona Model has incorporated conjunctive use into a larger policy framework. Conjunctive use is discussed further in Section 9.2.2.

Several specific management tools are specified in the law. Each of these tools is applicable to every AMA:

- Permits for all new users;
- Pump taxes for all users except withdrawals from exempt wells;
- Mandatory conservation, by which the amount of water rights for users gradually are diminished over time;
- Permanent retirement of some irrigated lands;
- Assured supply, or prohibition of development of new subdivisions without assurances that enough water exists for 100 years; and
- Augmentation programs.

B. Current Status

The Arizona Model is noteworthy because of the extent to which authority is concentrated in the DWR.[1] This degree of centralization is particularly unusual for ground water policy, which typically has been governed by legal structures which favor individual or private rights and restrict state roles. No other state has developed such a strong state management approach, although Florida comes close in some respects. The potential longevity of the Arizona Model has received some attention, given its radical departure from the prior system and the extent to which it restricts strong agricultural interests in the state (Kyl 1982). The Arizona law is likely to continue to receive yearly legislative challenges in the form of amendments, and it has had two serious constitutional tests in Arizona's supreme court. In both cases, the court upheld the authority of the state to use its police powers to regulate ground water resources (Kyl 1982, 495).[1] The law contains a "nonseverability" clause which states that no part of the law can be invalidated without overturning the entire law. This clause was included explicity to discourage incremental changes.

---

[1] Some checks do exist on the authority of the DWR. Those affected have the opportunity for administrative review, and specific statutes guide many decisions about meeting the goals of the act.

C. Advantages

The fundamental advantage of the Arizona Model is that it maximizes state control over ground water resources and related growth. Such control is particularly important for severe problems, as ground water overdraft is in Arizona, and when states face rapid growth or economic change which is not easily accommodated within existing policy frameworks. This certainly is the case in Arizona as agriculture has declined and mining and municipal interests have grown. Because of its comprehensiveness, the control exercised by the director of the DWR, and the number of management tools included, the Arizona Model allows the state to have much more control over the allocation of ground water among competing interests.

The state did consider other regulatory and administrative approaches. For example, the ground water management study commission, created in 1977 to suggest solutions to the state's ground water problems, explicitly considered local administration through AMA's. After nerly three years of study, it recommended centralized state control as the best way to develop expertise and evenhandedness of ground water management (Kyl 1982, 483). More "free market" approaches to deal with ground water also were considered but rejected, primarily because ground water was viewed to be so critical to the economy and welfare of the state, and because ground water overdraft was considered too far advanced to expect a solution by economic forces. Thus, immediate management including mandatory conservation was considered necessary to reduce agricultural water uses and to regulate existing and new municipal and industrial uses. Considerable opposition existed from industrial and municipal interests to "free market" proposals which would reward farmers by requiring other potential users to purchase rights largely held by farmers (Connall 1982). The legislature adopted the state regulatory approach, in part because it allowed the state to prioritize uses without the necessity of purchase.

---

[1] Town of Chino Valley v. City of Prescott. 638 p. 2d 1324 (Arizona 1981). In essence, this case held that landowners do not own the ground water beneath their land; their right was only to use the water. Thus, the law was ruled not to take property rights. The state recognized some existing uses as grandfathered and required new uses to conform to the ground water act. Technically, no rights were transferred. In Cherry v. Steiner, the Arizona Supreme Court upheld the entire code as a valid exercise of police power.

The Arizona Model also includes strong enforcement capability, both in terms of specific enforcement mechanisms and by concentrating enforcement capability in the director of the DWR. Specific enforcement mechanisms are:

- Reporting: all water users in AMA's must file annual reports to the director of DWR regarding water withdrawals, use, and transportation;
- Inspection: all facilities for withdrawing, using, or transporting ground water are subject to inspection and audit by the director of DWR;
- Cease and desist orders may be given for violations of the law;
- Civil penalties up to $10,000 per day for illegal withdrawal, use, or transportation; and
- Criminal penalties, ranging from misdemeanors to felonies for knowing violations and falsification of measuring devices.

An enforcement fund was established to enhance this capability, consisting of an original $100,000 appropriation and all fines collected for violations. The law also authorizes a ground water withdrawal fee to be levied ($5/acre-foot) on each user within an AMA. Up to $1 of this fee may be earmarked for administration and enforcement.

The Arizona Model also has substantial flexibility. By establishing AMA's, the state can target its management efforts to critical locations and use different management tools depending on locational circumstances. For example, conservation may be much more necessary in some high growth areas such as Tucson than in other areas.

D. Disadvantages

Two primary criticisms have been made about the Arizona Model--the loss of local control, and the inefficiency of public sector regulation. The question of local vs. state control was a recurring issue throughout the negotiations over the law. In fact, the Ground Water Management Study Commission's draft report recommended that AMA's be responsible for administration and management and that the DWR be responsible for oversight and enforcement. This recommendation was based on the belief that effectiveness would be enhanced if local conditions and patterns of use were recognized in the administrative structure (Higdon and Thompson 1980, 634). This recommendation was later reversed; while local advisory committees were established to incorporate local perspectives, it is clear that overall responsibility rests with the DWR. Local administration also might enhance overall flexibility within the state, if AMA's are given primary management responsibility and variances are allowed across AMA's, a greater variety of uses could be encouraged. This kind of diversification within the state was not considered to be an advantage for Arizona, which wanted to restrict agricultural uses in areas of overdraft or competing demands from municipal and agricultural users. However, this diversification could be an advantage for other states with different priorities or less severe problems.

A second major issue in the Arizona Model regards the capability of the free market to solve the overdraft problem. A minority report of the Commmission, largely representing agricultural interests, contended that considerable agricultural land had already gone out of production because pumping costs had made farming uneconomical in many areas. The minority also argued that, since municipal and industrial users could afford higher pumping costs, water would still be available to them after agricultural users had stopped production. Presumably, as irrigated agriculture became more uneconomical, conservation of water would be a natural result of the free market (Kyl 1982, 499-500). In addition, the free market approach would avoid the costs associated with the creation of a large state bureaucracy.

Other issues have been raised with the Arizona Model. Hidgon and Thompson (1980, 645-46) criticize the law for continuing to distinguish ground water and surface water. Arguing that all waters are hydrologically interrelated and interdependent, they suggest that the law should treat water as a single resource. As the law now stands, any enforcment of it which infringes on the rights of surface water is likely to lead to a legal challenge, on the grounds that the state could be taking property without just compensation. If the right to use surface water is determined not to be a constitutionally protected property right, then the distinction between surface and ground water would no longer be an issue.

Achieving safe yield in 45 years may be difficult. The use of over two million acre-feet would have to be eliminated during a time when the state is projected to have a doubling or tripling of its populaton and increased industrial growth (Kyl 1982, 493). However, water from the Central Arizona Project will provide the equivalent of about two-thirds of present overdraft (Ferris 1983). To try to achieve safe yield, largely at the expense of agriculture, is opposed by agricultural users and their powerful infrastructure (ditch companies, conservancy districts, etc.). These groups may try to amend the code legislatively depending on political conditions, as well as to challenge it in the courts. Because of the law's nonseverability aspect, it would be possible to have the entire law invalidated because of one technicality.

E. Feasibility

The unusual circumstances which led to the passage of the Arizona law could be interpreted to suggest that the model cannot be adopted in other states. The most unusual of circumstances were: (1) the severity of ground water overdraft in Arizona--ground water levels in many aquifers were as low as 700-1000 feet;[1] (2) the speed with which it was passed--it required less than eight hours from introduction to final passage; and (3) the intervention of Secretary of Interior Andrus who threatened to delay the Central Arizona Project unless Arizona improved its management capacity.

However, too much can be made of these unusual circumstances, particularly federal intervention which has been the focus of much of the public discussion (Kyl 1982). In fact, several other factors contributed to the adoption of this legislation. These factors include a long and well-known history of nonmanagement of water resources which gradually led to increased pressures for new policy; (2) strong gubernatorial and legislative leadership; (3) painstaking political groundwork in the form of the Ground Water Management Study Commission; (4) rapidly changing state economic conditions, particularly increased demands for water from industrial (largely mining) and municipal interests; and (5) a desire to restrict water usage by agriculture (Higdon and Thompson 1980; Kyl 1982, 481).

Indeed, the work of the Ground Water Management Study Commission represents a model of how to adopt a controversial new policy. Created to study the severity of ground water overdraft, the Commission became an institution for compromise among mining, municipal, and agricultural interests. While it was clear that industry and municipal interests had the balance of power on the Commission, agricultural interests participated in the hope of having some influence rather than risk passage of a law even more adverse. While it took over two years to forge a compromise, requiring relentless pushing by the Governor and legislative representatives, a fragile compromise finally was developed. The fragility of the final proposal was apparently important--the compromise was so tenuous that it helped to prevent legislative debate which could threaten the entire proposal (Kyl 1982, 479).

Along with the changing political and economic power structure in the state, particularly the decline of agriculture, the work of the Commission was substantially more significant to the adoption of the Act than was the intervention of Secretary Andrus. These changes along with the other factors favoring the Arizona Model, suggest that this should not be considered an isolated response to a unique problem. Indeed, many of the factors leading to its adoption, particularly increased pressures for growth and stress on a critical natural resource, also have steadily increased in some areas of the southeastern United States.

---

[1] For comparison, ground water levels in some of the most depleted wells of the Ogallala acquifer have been reduced to 120-150 feet below the land surface (Texas Department of Water Resources 1980).

9.3.2 The Nebraska Model

A. Description

Nebraska's system for ground water management is an incremental model which approximates a decentralized or "bottom-up" approach. The model is incremental in that Nebraska ground water law, in contrast to the prior appropriation doctrine applied in most western states, has been developed at common law through case-by-case decisions. Recent rapid development of irrigation in Nebraska has led to increasing legislative interest in modifying the framework for resolving ground water problems and issues. It is a decentralized model since major management responsibility rests with local districts with fragmented authority vested in several state agencies.

In contrast to Arizona and Florida, both of which enacted comprehensive ground water legislation in response to unique and almost crisis conditions, the development of ground water legislation in Nebraska has been more piecemeal. Nebraska has had a strong tradition of common law allocation for ground water, quite different from that of neighboring states, reflecting the seeming abundance of supplies in the first half of this century. However, Nebraska expanded use of ground water for irrigation so rapidly during the 1960s and 1970s that by 1978 over 71 percent of irrigation water was obtained from ground water sources (Bentall 1978). The introduction of the center-pivot irrigation system in particular played a key role in accelerated ground water pumping by making it possible to irrigate hilly areas and sandy soils such as the Sandhills region (Fricke and Pederson 1979).

This accelerated development of ground water for irrigation as well as other uses appears to be dramatically altering the distribution of ground water across the state (Fricke and Pederson 1979; Gessaman 1981). For example, declines in ground water aquifers have been estimated for several basins in western, southwest, central, south central and north central Nebraska. On the other hand, ground water mounding (rises) attributed to deep percolation from storage reservoirs, canals, and distribution systems of surface water irrigation systems has been detected in some south central and central Nebraska basins. Thus, although total ground water supplies may not be changing, some areas are experiencing withdrawals at rates which greatly exceed natural recharges. These include the Upper Republican, Upper Big Blue, and the Upper Little Blue River Basins (Gessamen 1981).

The key legislation defining state and local roles in managing ground water in Nebraska is the Ground Water Management and Protection Act (1975, as amended in 1981, 1982). This act authorizes administrative controls on ground water development and use in ground water control areas. In contrast to other western states and Arizona in particular, the local governmental units have the responsibility for establishing these controls in the absence of any state ground water management goals or objectives (Aiken 1980). Under the provisions of the Act, the existing 150 single-purpose districts were replaced by 24 Natural Resources Districts (NRD) organized along river basin lines, financed by property taxes, and governed by locally elected board of directors assisted by a professional manager (Aiken 1980; Fricke and Pederson 1979; Gessaman 1983). These NRD's have broad natural resource management responsibilities, including soil and water conservation, flood and soil erosion control, drainage, water supply, pollution control, wildlife habitat management, recreation, and forestry and range management. In regard to ground water management, the NRD's have the exclusive authority to initiate the process of designating ground water control areas (Aiken 1980).

These districts essentially have two types of direct initiatives they can take to manage ground water. First, a NRD can request the Director of the State Department of Water Resources (DWR) to hold a public hearing to determine whether or not local conditions meet the legal requirements for designation as a ground water control area. Based on a hearing, if the DWR Director finds that uncontrolled use of ground water in the district will result in either inadequate supplies for present or future needs or pollution of ground water rendering the water unsuitable for current uses, the director may designate a control area. Once an area is designated, the NRD may develop regulations such as withdrawal limitations, well spacing requirements stricter than those already provided for in other legislation, and moritoria on well drilling. Additional irrigation development in such an area would have to meet only those regulations applied to existing irrigated land at the time the regulations were adopted--in other words, future development would not be penalized (Gessaman 1983).

Second, ground water management areas may be designated within each NRD, based on a ground water management plan prepared by District officials and reviewed by the DWR Director. A key element in this relationship between the local district and the Director is that, although district officials must respond to concerns raised by the Director about the plan, the Director can not require changes or prevent implementation of the plan (Aiken 1980; Gessaman 1982, 1983). This plan must include ground water management objectives which incorporate a proposed ground water reservoir life goal for the area. The district plan must indicate the amount of ground water that could be withdrawn annually consistent with the stated life goal and demonstrate management controls consistent with those goals.

Because of the broad responsibilities of the NRD's and other local governmental units, other less direct but powerful tools for managing ground water use and protecting ground water quality are available. In addition to the authority to initiate the process for establishing control areas, the Ground Water Management Protection Act as amended gives the NRD's the authority to regulate, with DWR approval, ground water irrigation runoff and the option to enforce state ground water statutes defining and controlling the construction or use of illegal wells. Nebraska statutes also authorize the adoption of land use regulations or mandatory conservation practices by the districts "in the interest of conserving soil and water resources and preventing and controlling soil erosion...." Enactment of such practices requires approval of 75 percent of the landowners in a district wide referendum and none of the proposed practices can be in conflict with any land use regulation legally adopted by any other local governmental unit (Gessaman 1982).

Rural zoning is also available to counties in Nebraska. A County Board of Commissioners or Supervisors can appoint a county planning commission and charge them with the preparation of a comprehensive plan and proposed rural zoning regulations. Public hearings on the proposed plan are required prior to presentation to the Board; for proposed zoning regulations, public hearings must be held by the Board prior to adoption. Such planning and zoning actions are reviewed annually by the Policy Research Office of state government but only to ensure that procedural requirements are met (Gessaman 1982).

Despite the emphasis on NRD development of initiatives to manage and protect ground water and the historical reliance on the discretion of individual landowners in allocation of ground water, several state agencies maintain important roles in the management and administration of ground water statutes and programs. The Nebraska Department of Water Resources administers a number of programs affecting ground water development and use (such as well registration and abandonment, withdrawals from pits near streams, interstate transfers of water, and intrastate transfers of water for public supplies) and coordinates the designation and administration of ground water control areas (Aiken 1980; Gessaman 1983).

The state's Department of Environmental Control is responsible for water quality protection generally and the Department of Health is responsible for drinking water quality although the NRD's have had the authority to establish control areas based on threats to ground water quality as well as availability since 1981. The University of Nebraska Conservation and Survey Division collects ground water use and quality information, the Natural Resources

Commission has responsibility for state water planning (Gessaman 1981), state funds for natural resources development, and the natural resources data bank information system (Aiken 1980).

B. Current Status

Within the past 5-7 years, several states have proposed or adopted elements of such a decentralized approach. For example, Colorado has developed ground water districts and Florida's Water Management Districts have significant administrative authority. Decentralized management also has been used for water quality management by the Ohio River Valley Sanitation Commission and the Texas Gulf Coast Waste Disposal Authority. Utah proposed a similar, decentralized approach in 1977 which would have integrated water quality and use management within local hydrologic units. Although receiving generally positive review, the plan was vigorously opposed by agricultural interests and ultimately rejected by the state legislature (Science and Public Policy Program 1982).

C. Advantages

Nebraska has made a strong commitment to local autonomy in determining ground water use management goals, objectives, and implementation strategies. It has organized the state into natural resource districts which have some relationship to water basins, given the districts authority to manage a range of resources and enforce programs which are interrelated, added authority to control ground water development or uses which threaten the quality of the resource, and backed this up by empowering the districts to raise revenues to support its activities. Checks have been provided by requiring hearings, referenda, and periodic reviews.

The primary reason for the development of the Nebraska Model is that it accounts for the unique characteristics of individual basins or planning districts. On a state-wide basis, considerable flexibility is gained both in terms of targeting management strategies to specific problems and in allowing different preferences for ground water use across the state. Participation by affected interests is enhanced by this option, compared to centralized approaches, since various groups are likely to perceive that they have more control over administrative agencies which are close at hand. While this may increase the time required for initial plans to be developed, accommodation among conflicting interests in the beginning stages may reduce the conflict, litigation, and delays often associated with new management approaches. An implication of increased participation is that public discussion about ground water issues will increase, which also will enhance public education.

D. Disadvantages

Experience with local ground water management in Nebraska seems to be inconclusive. No attempt has been made to establish a ground water pollution control area since the quality protection provisions were authorized in 1981. Under the provisions of the 1975 act, six hearings have been held; three resulted in the designation of control areas. Of these three, only one, the Upper Republican NRD in southwestern Nebraska, has actually developed, received approval, and begun to implement a ground water management plan. The other two areas, the Upper Big Blue NRD and Little Blue in southeastern Nebraska, have developed preliminary regulations but have been blocked by citizens' petitions (Fricke and Pederson 1979; Gessaman 1982, 1983). Not only is it too early to tell how effective these controls have been in protecting ground water supplies, it is also likley that other changes within the agricultural community and the economy in general will confound efforts to interpret the results. For example, the costs of pumping ground water in some areas, increased knowledge by farmers of the impacts of loss of fertilizers, and benefits of improved irrigation schedules and techniques may induce more cautious use of ground water by the agricultural community (Gessaman 1983).

It is also difficult to characterize what the Nebraska model will look like in the near future. For example, the requirement that persons withdrawing ground water from a Nebraska well for use in an adjoining state get a permit from the Department of Water Resources was rejected by the U.S. Supreme Court (Sporhase v. Nebraska, ex rel Douglas 1982) because the reciprocity clause violated the Commerce Clause of the U.S Constitution. However, the court did hold that the three conditions Nebraska specified for the granting of a permit--that the withdrawal be reasonable, not contrary to the conservation and use of ground water, and not otherwise detrimental to the public welfare--are not explicit barriers to interstate commerce and therefore are legitimate concerns for state regulatory decisions. Thus, although much has been made over this decision because of its implications for Congressional involvement in ground water regulation based on the Commerce Clause, the decision is also important for states like Nebraska which have no constitutional provisions for regulation of ground water resources combined with a strong nongovernmental tradition in allocation. The decision essentially supports the position that a state does have a right to regulate ground water withdrawals when they threaten public interests in sufficient supplies.

A major question with the Nebraska Model concerns intergovernmental relations. The potential for conflicts among various levels of government is considerable because the approach tries to maximize local autonomy and participation while still retaining the traditional state functions of setting priorities, providing oversight, and administering environmental programs. Moreover, the idea of increasing local authority over natural resource protection is controversial, largely because of questions about the adequacy of local institutional capacity. To some extent this issue is being addressed through the State Water Planning and Review Process (SWPRP) which requires an integrated statewide water resource planning effort. This was the result of two separate pieces of legislation enacted during the 1978 session after efforts to compromise on water legislation issues failed (Gessaman 1981). Conceptually, the SWPRP brings together university expertise, governmental administrative and budget resources, and public participation channels to facilitate analysis of alternatives for managing resources. This process has improved information bases, involved constituencies, and increased publicity on water issues. Yet it can not resolve basic conflicts between agricultural users currently dominating NRD boards (and industrial users who depend on irrigation) and the other Nebraska citizens who value ground water for other uses, including future water supplies and aesthetic or ethical values (Gessaman 1981).

The ability of NRDs to use land use or conservation management tools to protect ground water resources is also relatively untested. To date, no NRD has attempted to adopt mandatory conservation practices. This results from several factors: a fuzzy definition of those eligible to vote in a referendum of landowners which would raise questions about the legality of any results; the lack of precedent for the referendum which increases the probability of court challenge by opponents of the outcome; and the apparently low probability of obtaining a 75 percent favorable vote in a state as heavily dependent on irrigation and as individualistic as Nebraska (Gessaman 1982). Although no legal impediments to rural zoning seem to exist in Nebraska, it has not yet been implemented as a way to control irrigation development, although many counties have used it to regulate the type and intensity of agricultural land use (Gessaman 1982).

E. Feasibility

The Nebraska Model is not a strong management approach; thus, it does not seem appropriate for states facing severe problems or states which want to exert strong influence on statewide water uses. Because so many aspects of the model are still developing, firm conclusions about its effectiveness are not warranted. However, among the most important questions for this approach is the capacity of local districts to control current water users.

The Nebraska Model does provide a useful experience for states which hesitate to adopt comprehensive regulatory frameworks such as those adopted in Arizona and Florida. In states such as these which may have political difficulty establishing strong, centralized state controls over ground water development or which may not want to initiate comprehensive state regulation of ground water, the Nebraska Model may provide a way to proceed. Given the historical, political, and cultural factors in states which have had a more "laissez faire" approach to water allocation, the incremental, decentralized approach may be a much more feasible way to accomodate strongly conflicting interests. Further, if it is indeed based on consensus, the implementation should proceed with less opposition.

The Florida Model

A. Description

A third approach to improving regulatory and administrative capacity is a mixture of the centralized and localized approaches found in Arizona and Nebraska. With the passage of the Water Resources Act of 1972, (Florida Statutes, Chapter 373) and its later amendments, Florida has developed one of the nation's most comprehensive planning and regulatory programs for managing water resources. It combines centralized and localized administration by creating a centralized state agency with authority to regulate and coordinate, the Department of Environmental Regulation (DER), while also granting primary responsibilty for water use management to five local water management districts. These districts are drawn along surface drainage and hydrogeologic boundaries and take into consideration the relationship between surface and ground water (Morandi and Lazarus 1982). In addition, the Florida Model includes the following elements (Howells 1978, 16-18):

- Conjunctive use of surface and ground water is an integral part of the regulatory system;
- Water quality and water availability are integrated in the planning process;
- Considerable attention is given to coordination of water resource management and land use planning;
- The law empowers the state to designate critical use areas; and
- Water management districts are required to prepare plans for coping with emergency situations (principally, shortages).

Prior to the implementation of the Water Resource Act, legislation and water management had been generally reactive to problems and emergencies as they arose. The unique two-tiered approach embodied in the Act recognizes the need to take into consideration important regional variations within the state while, at the same time, providing overall planning and coordination through a centralized administrative agency (DER). This agency is responsible for the development of the State Water Plan which is intended to be a combination of the State Water Quality Plan and the State Water Use Plan (Maloney and Hamann 1981). It is anticipatory rather than reactive. In addition, the DER is the principal agency responsible for water quality management. Although the Water Resources Act also gives DER a supervisory role with respect to water use management, these functions are performed by the water management districts.

As they carry out their water management responsibilities, each district is governed by a nine-member board appointed by the Governor and confirmed by the Senate. Members reside within the district and serve four year terms without compensation. The board elects a chairperson from among the members and is authorized to employ an executive director and other technical and legal staff (Wershow 1977).

The governing boards have substantial regulatory authority to carry out their statutory responsibilities for water use management. They are empowered to: (1) issue permits for consumptive use; (2) regulate wells, including setting standards for construction, repair, and abandonment; (3) regulate surface water management systems; (4) develop and implement water use plans, including water shortage plans; and (5) levy ad valorem taxes to help finance their activities (Maloney and Hamann 1981).

However, not all districts have used this authority to the same degree. The South Florida and Southwest Florida Water Management Districts have made the most progress in developing and implementing water management systems based on their regulatory authority. For example, both districts have fully operating consumptive use permitting systems. The St. Johns system applies only to water uses in designated areas and the Suwannee and Northwest Florida Districts have prepared preliminary permitting programs for designated areas. These programs should be adopted sometime in 1983 (Morandi and Lazarus 1982).

Although no water management district has a finalized Water Shortage Plan, the South Florida District has completed a draft plan that will probably serve as the model for other districts to follow. These plans are intended to delineate specific classifications of use that will be curtailed in the event of a drought or other water emergency, outline the plan for implementing such a curtailment, and provide guidelines for ensuring efficiency and certainty in crisis management decisions. The South Florida District has also been an example to other districts in "integrating other resource considerations into water allocation decisions through its review of the water quantity, quality, and land use impacts of proposed construction activities within its permitting jurisdiction" (Mordandi and Lazarus 1982, 96).

The fact that each district has not developed its management capacity to the same degree reflects, in part, the independence of the districts and the diversity of viewpoints regarding water management. The differences in management programs is also the result of the types of problems that occur in each geographic region, the experience and expertise of the technical staff, the pressures of competing interests within the districts which, in turn, interface with the basic water mangement philosophy of the governing board (Wershow 1977).

Because of the independent nature of the districts and the two-tiered organizational structure, an effort has been made to increase the coordination between the Department of Enviornmental Regulation and the water management districts. Several coordinating mechanisms have been developed: a full-time coordinator was appointed within DER to act as a liaison between the agency and the districts, quarterly meetings of district and state staffs are required, and a newsletter to communicate between the state and the districts was developed. In an attempt to better coordinate water quality and quantity concerns, four regional offices of the DER were established. To the extent possible, the boundaries for these offices were developed to coincide with the five management districts; the offices are colocated with district offices to enhance communication and coordination.

B. Current Status

Florida's comprehensive water management plan has been in existence for approximately ten years. During this time it has been subject to considerable legislative revision; for example, significant changes were made in the ground water provisions in 1979, including designation of a separate ground water section in DER (DeHan 1981). In addition, several other pieces of legislation were purposefully coordinated with the Water Resources Act--such as the Local Government Comprehensive Planning Act of 1975 and the Environmental Reorganization Act of 1975. Thus, Florida's water management system has experienced substantial institutional development since 1972 and appears to be an accepted part of public sector activity in the state.

In comparison to other states, Florida's Model appears unique in separating water use functions at the state level from water quality functions at the district level. In large part, this reflects historical patterns of local independence and control. Both New York and Wisconsin have developed strong regional offices to perform some management functions, such as permitting. However, no other state parallels Florida's mixture of state, district, and regional offices.

C. Advantages

If comprehensive, integrated management of water resources is desired by a state, the Florida system could be a valuable model. This innovative approach combines many elements of both the Arizona Model and the Nebraska Model--a centralized administrative agency at the state level with relatively autonomous local management districts. In addition, both major components are supported by several formal and informal coordination mechanisms intended to reduce intergovernmental barriers to effective management.

Even though some confusion exists about the coordination of certain DER and district functions and the independent nature of the districts makes statewide coordination of regional activities difficult (see below), opportunitites do exist for the coordination of land use and water resource planning among the state, the water management districts, local governments, and the regional planning councils. The Local Government Comprehensive Planning Act of 1975 requires that comprehensive development plans be subject to state approval. This is an attempt to ensure "consistency and coordination"; that is, each of the elements of the plan must be consistent with each other and permitted activities must be coordinated in order to achieve consistency (such as between the water management districts and local governments) of purpose (Morandi and Lazarus 1982).

Some of the water management districts have developed multiple, formal mechanisms for coordinating land use and water resources planning with local governments and regional planning councils. For example, the Northwest Florida Water Management District:

- Enters into memorandas of agreement with the Apalachee Regional Planning Council and the West Florida Regional Planning Council directed at coordination of planning, program review, and review of developments;

- Has established five Basin Advisory Committees that include representatives of all county governments and major municipalities. The committees meet with the district Governing Board member appointed from the specific basin and the district's Executive Director and Division Directors twice yearly to coordinate water management needs and programs;

- Established a 30 member Policy Advisory Committee composed of representatives of local, county and state government, the Florida Legislature, chambers of commerce, major industries in northwest Florida, regional planning councils, and special interest groups. This committee provided advice during the development of the district's Water Resource Management Plan in order to coordinate with the needs and interests of the various groups represented;

- Provides technical assistance at the request of any governmental entity in northwest Florida to make available needed planning support and coordination between water resource management and other concerns (Florida House of Representatives 1983, 206-07).

The coordination of land use and water resource concerns in some other districts is much less formal and at a much reduced level compared to the Northwest District. Except for the Floodplain Management Program, the Suwannee River Water Management District has had relatively little planning contact with local governments. The district is beginning to develop a closer working relationship with local governments through the Floodplain Management Program and may become more involved in local planning programs in an advisory role related to water resources. The district also participates in the Development of Regional Impact reviews performed by the North-Central Florida Regional Planning Council but there has not been any formal liaison process for coordinating the planning programs of the district and the planning council. Through the Floodplain Management Program, permanent liaison is being established with the Suwannee River Committee of the planning council which is expected to lead to better coordination (Florida House of Representatives 1983, 211-12).

Thus, while problems continue to exist with coordinating and integrating the activities of the five regional water management districts and with coordinating the functions of the DER and the districts, continual modification and revision has lead to progress in dealing with these issues. In addition, positive steps have been taken to more systematically integrate the concerns and interests of groups from all levels--state, district, local--with respect to land use and water resource management issues. Florida has made substantial progress toward developing and implementing a comprehensive surface and ground water management system.

D. Disadvantages

A major issue with the Florida Model, as identified above, is the statutory split between the Department of Environmental Regulations' water quality responsibilities and the districts' water quantity and flow control. The bifurcation of water management functions overlooks the fact that water quality and quantity considerations are not usually mutually exclusive. This has resulted in confusion with respect to the districts' authority and responsibility when evaluating permit applications for consumptive use (quantity) but which could have a negative impact on water quality. Should the districts ignore potential water quality impacts and judge the request only on quantity considerations and require an applicant to get approval of water quality considerations from the DER under a separate permit? Or, should they assess water quality impacts also and take on the statutory responsibility of the DER? At the same time, any negative quality impact could be viewed as tantamount to a nonreasonable and nonbeneficial use of the resource. Thus, should the water management districts be involved in any permit decision made by the DER concerning quality issues that could impact on the availability of the districts' water resources (Florida House of Representative 1983)?

The confusion over the scope of authority of the districts in the permitting process has lead to duplication of effort, lack of clear direction to the permit applicants, and wasted time and expenditures (Wershow 1977). As part of its study of water resources issues, the Florida House of Representatives Speaker's Task Force (1983) asked the districts about the difficulties and benefits of managing water resources given the separation of quality and quantity aspects. The districts stressed the importance of looking at both quantity and quality parameters in order to understand the whole water management picture and indicated that redundant evaluations of both aspects takes place, rather than separate evaluations. Better coordination and communication between DER and the districts is viewed as essential for ensuring consistency between the permitting systems and to eliminate wasteful duplication.

While all districts agree that coordination is a required element of the two-tiered organization, some indicated that the separation can be beneficial in helping to achieve a "balanced" consideration of quantity and quality issues. In addition, limited responsibility permits a particular organization unit to develop extensive experience and expertise because of the ability to specialize in quantity or quality.

On the other hand, some of the districts welcomed the opportunity to accept the delegation of water quality responsibilities from the DER. The Department has recently delegated responsibility to regulate stormwater discharge to the South Florida Water Management District. DER is in the process of delegating water well contractor licensing to the Northwest District, and the stormwater portions of the ground water rule to the South Florida District (Florida House of Representatives 1983, 96). Some of the districts have expressed interest in accepting responsibility for other DER programs depending on their capability to administer them. Further delegations will depend, to some degree, on financial considerations within the districts. Without adequate funding, the districts are not going to be willing to increase their level of activity.

Shortly after enactment of the Water Resources Act, the first National Water Commission (1973) suggested that the Florida water management system relied too heavily on administrative discretion at the local level with only the vaguest of standards and guidelines from the state level. Although modifications have been made since that time and coordination efforts have increased, this apparently is still the case and has contributed to stress between the districts and the DER, particularly as the DER has tried to coordinate activities among the districts. The districts continue to maintain a high degree of independence (Howells 1978). For example, the DER has attempted to integrate state and regional authority in the development of the State Water Plan. However, although the DER may designate certain desirable uses to be given priority in granting local permits and these preferences must be recognized by the districts, the districts are not required to deny permits for activities determined by the DER to be undersirable (Morandi and Lazarus 1982).

Further, the districts have been given an advisory role in the development of the State Water Plan in an attempt to integrate and coordinate the activities of the districts; however, the independence of the districts inhibits this process. This is particularly the case with the South Florida and Southwest Florida districts--the forerunners of these districts began preparation of regional water use plans before the DER was even established. In general, the DER has been at a disadvantage in attempting to integrate planning and management for water resources on a statewide basis because of the conditions within the districts--they have independent financial resources through their taxing authority, regulatory control through consumptive use permitting, and they have already begun implementing regional water use plans (Morandi and Lazarus 1982).

E. Feasibility

Florida's comprehensive management of water resources reflects several factors, including its relatively unique geohydrology which makes its surface and ground water so closely connected, and its rapid growth over the past few decades which has forced natural resource issues to the top of the public agenda. However, Florida's Water Resources Act also reflects a long, cumulative process of recognizing the necessity of public water management--in fact, recognition of the need for active water management can be documented fairly continuously in Florida since 1931 (DeHan 1981, 12).

The Florida situation contrasts with that of many states which have considered improvements in their water management policies. The state does not face continuous or severe shortages; rather it is fairly constantly fluctuating between too much water from large storms to not enough water. This unusual situation has contributed to the extent to which the state has regulated water resources. However, the administrative arrangement which combines centralized and localized approaches is based on a very important consideration --problems, needs, and priorities differ across the state and need different management approaches. Very few states will be able to develop a uniform water management system that will be applicable to the needs of every geographic area of the state. A system which combines local autonomy with statewide coordination allows for regional diversity but not to the point that it is dysfunctional to the states overall well-being. If Florida's experience is successful, particularly in coordinating the functions of management districts with those of the DER, this administrative model appears to be feasible for many other states.

9.3.4 Summary of Regulatory Models

Table 9-6 summarizes the experiences of Arizona, Nebraska, and Florida in managing ground water. The primary issues concerning these models are the relative advantages of centralized compared to localized regulatory frameworks, coordination among levels of government, and the feasibility of these models for other states.

The Arizona and Florida models both exert strong, active management approaches to ground water. They also are fairly comprehensive in reforming the legal and administrative structure and in developing specific management strategies. The Arizona Model appears to be advantageous if the goal is to maximize state control over ground water resources, allowing the state to determine fundamental issues of how water resources will be allocated among competing demands.

This model appears most appropriate in areas where problems are serious or if the state goal is to change past water use priorities over a relatively short time frame. Similarly to the Arizona Model, the Florida Model provides a comprehensive, active management approach. In contrast, by balancing state with local authority it is somewhat less suitable for encouraging substantial changes in existing uses.

By incorporating a critical use concept, both the Arizona and Florida Models provide a flexible approach within the larger goal of comprehensive, active management. The Florida Model is the most flexible in terms of allowing a diversity of water uses and management tools to be used, since each district has considerable lattitude in planning and developing its own approach. The Arizona Model is flexible in allowing different management approaches in different local areas, but it has a much more sharply defined set of goals and programs than do the other approaches. If adopted in other states, the Arizona Model could incorporate a much wider set of management tools.

The Nebraska Model is much less comprehensive and does not concentrate authority at the state agency level. Local management districts have even more autonomy than in the Florida Model, since the Nebraska Model does not include a strong, centralized state agency and fewer formal coordination mechanisms are established

TABLE 9-6: SUMMARY OF REGULATORY MODELS

Option	Description	Current Status	Advantages	Disadvantages	Feasibility
• The Nebrasksa Model	A localized framework for ground water use. Based on the development of management districts which would develop plans, incorporate local interests, and develop management strategies tailored to local conditions.	Several states besides Nebraska have adopted the district planning idea, including Florida.	• Considerable flexibility is allowed within a state and management strategies can be tailored to local conditions. • Political accommodation is a major goal in the development stages.	• Several constraints to capacity of local areas to exert strong management control. • Establishing "control areas" will be difficult, based on the Nebraska experience.	Primarily feasible for states not facing serious problems or intense competition for resources; overall effectiveness is uncertain.
• The Arizona Model	Comprehensive management authority in one state agency to reduce ground water use and provide safe yield. Develop comprehensive management tools and strict enforcement capabilities.	Enacted in Arizona in 1980. No other state has developed such a comprehensive strategy.	• Allows comprehensive management of water resources. • Can be used as a growth management policy. • Has both short-term (crisis) and long-term (safe yield) provisions.	• Creates many political enemies who can reduce its effectiveness. • Restricts individual rights. • Increases size of state bureaucracy.	Comprehensive management may not be needed unless problems are severe. However, several of the conditions leading to consideration of a strong state role exist in the Southeast.
• The Florida Model	A mixed regulatory model which has a centralized state agency providing oversight, planning and regulation of ground water quality while localized management districts control water use.	Has existed for nearly 10 years, is well-accepted in the state, and has been subject to considerable alterations.	• Combines many elements of active, integrated management and planning. • Successful in fostering innovative institutional relationships to coordinate state and local programs. • Facilitates flexibility.	• Separates use and quality management. • Difficult to integrate planning and management elements. • Intergovernmental relations are a continuing barrier.	Florida's unusual water characteristics and problems make this solution somewhat unique. However, this is also a balanced and flexible approach which could be modified to fit different circumstances.

between the state and local districts. Perhaps an even fuller range of management tools could be used in this model, including free market approaches to management.

The Nebraska Model has the additional advantage of emphasizing political accommodation in the planning process. If this accommodation is successful, it could have a long-term benefit by reducing the conflicts and creating cooperative implementation mechanisms. In the short-term, emphasis on participation and political accommodation could substantially delay the development of the local management plan.

A critical question with the Nebraska Model is the capacity of local governments to manage ground water resources, given the economic power of many of the vested interests who favor existing institutions and policies and who may be able to influence local decisionmaking. If this occurs, there may be little improvement in management capacity. This consideration, along with desires to exert strong state control over ground water, led Arizona to reject localized administration.

Intergovernmental relations are an important concern in each model. An inherent state interest exists in ground water policy and, in most caes, a strong argument for local involvement and responsibility can be made. Coordinating state and local roles is apparently a problem in both the Nebraska and Arizona Models. In Nebraska, the problem is how to include the state in the formulation of ground water policy without jeopardizing localized planning and management. In the Arizona Model, local units are largely excluded from the policy process. The Florida Model is the only one in which considerable attention is given to coordination mechanisms, in the form of regional offices and a variety of communication mechanisms. If these mechanisms are successful, the Florida Model may have many advantages over the other two.

In summary, the Florida Model includes an important mixture of many of the elements found in the Nebraska and Arizona Models. Even though it has been developed in a state experiencing more severe problems than most other states, it provides a balanced state-local regulatory framework with flexible management strategies. Thus, its basic structure is applicable to other states experiencing less severe or more localized approaches. The Nebraska Model may also be adaptable to many other states, particularly those states which want to encourage a large local role in problem-solving. Its most serious constraint is that it does not facilitate state control over growth and natural resource issues. The Arizona Model may be the least transferable, largely because few other states face the severity of problems which Arizona has had for years. However, it is a myth that the Arizona Model was created in conditions unique to Arizona. Two of the primary causal factors--increasing natural resource constraints on

growth and increased competition among users--are occurring throughout much of the nation.

9.4 SUMMARY AND CONCLUSIONS

States have a variety of choices if they want to enhance their capacity to control ground water resources. This chapter has reviewed five options to improve institutional capacity and three overall state regulatory approaches currently being used. Consideration and adoption of these options will largely depend on:

- The existing legal and institutional structure;
- The severity and pervasiveness of ground water problems;
- The capacity of states to anticipate growth pressures; and
- Public and political awareness of the relationships between ground water, growth, and individual well-being.

While each of these conditions varies in the Southeast, it is clear that overall recognition and concern about ground water is increasing. Most southeastern states are likely to be faced with questions of whether to comprehensively revise ground water policy or to make incremental adjustments in response to specific problems. This question is largely one of political feasibility. The more comprehensive regulatory approaches--including the Arizona and Florida Models and reorganization to integrate quality and availability concerns--are likely to face considerable political resistance from vested interests in many states. More incremental choices, such as conjunctive use, emergency response, and cooperative supply, are more feasible for many states. Cooperative supply systems may be particularly attractive in areas such as Henry County, Georgia, where major questions exist concerning the development of ground water resources.

While these feasibility concerns are true in general, many southeastern states have taken measures to enhance administrative and management capacity. Florida, Georgia, North Carolina, and South Carolina have been particularly innovative in developing coordinated state-district regulatory approaches (Florida), integrated administrative structures (Georgia), and classification systems (North Carolina, South Carolina). Although Alabama has developed few ground water use management tools, it has centralized and coordinated its ground water quality agencies into the Alabama Department of Environmental Management. Mississippi has developed an emergency response capacity and has legislation authorizing critical use designation. Thus, the clear trend in the Southeast is towards active ground water management and enhanced institutional capacity.

As problems and demands increase, more states are likely to consider the specific options or general approaches discussed in this chapter. Since the conditions in each state are usually so different, there is no single option or approach which is likely to be applicable across the region. However, many states in the Southeast are developing valuable experiences in the development of ground water management institutions. These experiences should help other southeastern states and states in other regions. This appears particularly true regarding the development of centralized state agencies to improve the planning, coordination, and management of ground water. In the Southeast, Florida and Georgia have developed relatively unique approaches which appear to be working well.

REFERENCES

Aiken, J. David. 1980. "Nebraska Ground Water Law and Administrtion," Nebraska Law Review 59:917-1000

American Water Works Association. 1979. "Regionalization of Water Utilities." American Water Works Association Journal 71 (December): 697-707.

Arnold, Peri E. 1974. "Reorganization and Politics: A Reflection on the Adequacy of Administrative Theory." Public Administration Review 34 (May/June): 205-12.

Atlanta Regional Commission. 1980. Drought Management and Water Conservation (draft). Metropolitan Atlanta Water Resources Study. Atlanta, GA: The Commission.

Bentall, Ray. 1978. Staff, Conservation and Survey Division, University of Nebraska-Lincoln. Oral communication. As cited in Fricke and Pederson 1979, 545.

Blackburn, Anne M. 1978. "Management Strategies: Dealing With Drought." American Water Works Association Journal 70 (February): 51-59.

Broward County Planning Council. 1981. Potable Water Subelement of the Broward County Comprehensive Plan. Ft. Lauderdale, FL: Broward County Office of Planning.

Brunswick County Board of Commissioners. 1981. Brunswick County, North Carolina, Coastal Area Management Act Land Use Plan Update. N.p.

Clark, Robert E., and Arthur Arguedas, Jr. 1978. "Developments in Groundwater Law." Nebraska Law Review 57:283-94.

Clark, W. 1980. "Arizona Enacts Ground Water Management Law." Water Law Newsletter 3.

Cobb, E. E. 1981. "Conjunctive Management of Ground and Surface Water." In Ground Water Management: Proceedings of a Southeast Regional Conference, edited by James C. Warman, 218-28. Auburn, AL: Auburn University, Water Resources Research Institute.

Connall, D. 1982. "A History of the Arizona Ground Water Act." *Arizona State Law Journal* 2:

Council of State Governments. 1975. *Integration and Coordination of State Environmental Programs*. Lexington, KY: The Council.

Day and Zimmerman, Inc. 1982. *Miami-Dade Water and Sewer Authority Water Division Report*. Philadelphia, PA; Day and Zimmerman, June.

DeHan, Rodney S. 1981. "State Programs Related to Ground Water Management in Florida." In *Ground Water Management: Proceedings of a Southeast Regional Conference*, edited by James C. Warman. Auburn, AL: Auburn University, Water Resources Research Institute.

Ferris, Kathy. 1983. "Centralized State Management of Ground Water: The Arizona Case." Paper presented at annual meeting of the American Association for the Advancement of Science, Detroit, MI, May 26-31.

Florida House of Representatives. 1983. *Report of the Speaker's Task Force on Water Issues*. N.p., March.

Florida's Environmental News. 1981. "State Water Policy Adopted." 4 (August): 1.

Fricke, Carl A. P., and Darryll T. Pederson. 1979. "Ground Water Resource Managment in Nebraska." *Ground Water* 71:544-49.

Gessaman, Paul H. 1981. "Initial Perspectives on Nebraska's State Water Planning and Review Process." Dept. of Agricultural Economics, University of Nebraska-Lincoln.

______. 1982. *Irrigation in the Sandhills: Public Management Alternatives*. NebGuide G82-606. University of Nebraska-Lincoln, Cooperative Extension Service, Institute of Agriculture and Natural Resources, September.

______. 1983. Staff Economist, Cooperative Extension Service, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln. Telephone conversation, May.

Griffith, Evan L. 1978. "Southern California's Drought Response Program." *American Water Works Association Journal* 70 (February): 74-78.

Higdon, Phillip R., and Terence W. Thompson. 1980. "The 1980 Arizona Groundwater Management Code." *Arizona State Law Journal* 621-67.

Howells, David H. 1978. A Summary Report: Southeast Conference on Legal and Administrative Systems for Water Allocation and Management. Raleigh: University of North Carolina, Water Resources Research Institute.

______. 1980. Southeast Conference on Ground Water Management: A Summary Report. Chapel Hill: University of North Carolina, Water Resources Research Institute.

Hufschmidt, Maynard M., and Patricia Stevens. 1978. "The Administrative System for Water Management Including Water Allocation in North Carolina." In Legal and Administrative Systems for Water Allocation and Management, edited by William E. Cox, 194-220.

Hurd, Merna. 1979. "Regionalization Opportunities and Obstacles: A Case Study." American Water Works Association Journal 71 (December): 713-19.

Kundell, James E. 1983. Personal written communication, March 22.

Kundell, James E., and Vicki A. Breman. 1982. Regional and Statewide Water Management Alternatives. Athens: University of Georgia, Institute of Government.

Kyl, Jon L. 1982. "The 1980 Arizona Ground Water Management Act: From Inception to Current Constitutional Challenge." Colorado Law Review 53 (Spring): 471-503.

Ledbetter, J. Leonard. 1980. "Georgia's Water Management." In Georgia Water Resources: Issues and Options, edited by James E. Kundell, 31-34. Athens: University of Georgia, Institute of Government.

Maknoon, Reza, and Stephen J. Burges. 1978. "Conjunctive Use of Ground and Surface Water." American Water Works Association Journal 70 (August): 419-24.

Maloney, Frank E., and Richard Hamann. 1981. Integrating Land and Water Management. Gainesville, FL: Florida Water Resources Research Center.

Metropolitan Dade County Planning Department. 1979. Comprehensive Development Master Plan for Metropolitan Dade County. Miami, FL: Metropolitan Dade County, Board of County Commissioners.

Miles, Rufus E., Jr. 1977. "Considerations for a President Bent on Reorganization." Public Administration Review 37:155-63.

Morandi, Larry B., and Greg H. Lazarus. 1982. Water Resources Management: Issues and Policy Options. Denver, CO: National Conference of State Legislators.

National Water Commission. 1973. Water Policies for the Future. Washington, DC: Government Printing Office.

Peek, Harry M. 1981. "Ground Water Program, Problems and Needs in North Carolina." In Ground Water Management: Proceedings of a Southeast Regional Conference, edited by James C. Warman, 42-58. Auburn, AL: Auburn University, Water Resources Research Institute.

Reed, Gregory D. 1982. "Drought-Related Water Conservation Efforts in Missouri." American Water Works Association Journal 74 (March): 120-25.

Robie, Ronald B. 1978. "California's Program for Dealing With the Drought." American Water Works Association Journal 70 (February): 64-68.

Science and Public Policy Program. 1982. Water and Western Energy: Impacts, Issues, and Choices. Boulder, CO: Westview Press.

Seidman, Harold. 1975. Politics, Position, and Power: The Dynamics of Federal Organization. 2nd ed. New York: Oxford Univ. Press.

Sherwani, Jabbar K. 1980. Public Policy for the Management of Groundwater in the Coastal Plain of North Carolina. Raleigh: University of North Carolina, Water Resources Research Institute.

South Carolina. Governor's State Water Law Review Committee. 1982. Report and Recommendations. Columbia, SC: Office of the Governor, December.

South Carolina Wildlife Federation. 1981. Personal communication, June.

Sporhase and Moss v. Nebraska, ex rel. 1982. U.S. Supreme Court No. 81-613, July 2, as printed in 50 U.S. Law Week 5115-22, June 29.

Texas Department of Water Resources. 1980. Texas Water. Austin: The Department.

Trelease, Frank J. 1982. "Conjunctive Use of Groundwater and Surface Water." Rocky Mountain Mineral Law Institute Proceedings 27:1853-94.

U.S. Geological Survey. 1974. Summary Appraisals of the Nation's Ground Water Resources--Upper Colorado Region. Geological Survey Professional Paper 813-C. Washington, DC: Government Printing Office.

U.S. Water Resources Council. 1981. State of the States: Water Resources Planning and Management, Ground Water Supplement. Washington, DC: U.S. Water Resources Council.

Wershow, James S. 1977. "Water Management: The Future of Florida Legal Implications." The Florida Bar Journal 51 (March): 136-44.

Western Governors' Policy Office. 1978. Managing Resource Scarcity: Lessons from the Mid-Seventies Drought. Denver, CO: Western Governors' Policy Office.

Woo, Viviane. 1982. "Drought Management: Expecting the Unexpected." American Water Works Association Journal 74 (March): 126-31.